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A branched candlestick carved from a solid block of wood.

CARVING IN WOOD—[See page 264]

Atlantis*

And the Permanency of the North Atlantic Ocean Bottom

By Charles Schuchert, Peabody Institute, Yale University

In 1912 Prof. Pierre Termier, the director of the Geological Survey of France, delivered before the Oceanographic Institute of Paris a very interesting and stimulating lecture on the probable existence of Plato's Atlantis. This lecture is now published in English in the annual report of the Smithsonian Institution for 1915 (1916), pages 219-234. In his lecture the speaker drew a conclusion that needs to be examined, as it is of considerable imporatnce in paleogeography whether one is in harmony with it or not. Termier thinks it "A fair conclusion . . . that the entire region north of the Azores and perhaps the very region of the Azores, of which they may be only the visible ruins, was very recently submerged." This means that the area believed to have been submerged is at least equal to 40,000 square miles, and may be even far more than 200,000 square miles; it is said to have sunk quickly about 10,000 feet beneath the surface of the sea.

What are the facts that lead Termier to this very important conclusion? He relates them as follows:

Some cataclysms certainly have occurred, and they date only as from yesterday. I ask all those who are concerned with the problem of Atlantis to listen attentively and to impress on their mind this brief history; there is none more significant: In the summer of 1898 a ship was employed in the laying of the submarine telegraphic cable which binds Brest to Cape Cod. The cable had been broken, and they were trying to fish it up again by means of grappling irons. It was in north latitude 47° 0' and longitude 29° 41' west from Paris, at a point about 500 miles north of the Azores. The mean depth was pretty nearly 1,700 fathoms, or 3,100 meters. The relaying of the cable presented great difficulties, and for several days it was necessary to drag the grappling irons over the bottom. This was established: The bottom of the sea in those parts presents the characteristics of a mountainous country, with high summits, steep slopes and deep valleys. The summits are rocky, and there are oozes only in the hollows of the valleys. The grappling iron, in following this much-disturbed surface, was constantly being caught in the rocks by hard points and sharp edges; it came up almost always broken or twisted, and the broken pieces recovered bore large coarse striæ and traces of violent and rapid wear. On several returns, they found between the teeth of the grappling iron little mineral splinters, having the appearance of recently broken chips. All these fragments belonged to the same class of rocks. The unanimous opinion of the engineers who were present at the dredging was that the chips in question had been detached from a bare rock, an actual outcropping, sharp-edged and angular. The region whence the chips came was furthermore precisely that where the soundings had revealed the highest submarine summits and the almost complete absence of oozes. The fragments, thus torn from the rocky outcrops of the bottom of the Atlantic, are of a vitreous lava, having the chemical composition of the basalts and called *tachylyte* by the petrographers. We are preserving some of these precious fragments at the Musée de 'lEcole des Mines at Paris.

The matter was described in 1899 to the Académie des Sciences. Few geologists then comprehended its very great import. Such a lava, entirely vitreous, comparable to certain basaltic stones of the volcanoes on the Hawaiian Islands, could solidify into this condition only under atmospheric pressure. Under several atmospheres and more especially under 3,000 meters of water, it might have crystallized. It would appear to us as formed of confused crystals, instead of being composed solely of colloidal matter. The most recent studies on this subject leave no doubt, and I will content myself with recalling the observation of M. Lacroix on the lavas of Mount Pelée of Martinique: Vitreous, when they congealed in the open air, these lavas became filled with crystals as soon as they were cooled under a cover, even not very thick, of previously solidified rocks. The surface which to-day constitutes the bottom of the Atlantic, 900 kilometers (562.5 miles) north of the Azores, was therefore covered with lava flows while it was still emerged. Consequently, it has been buried, descending 3,000 meters; and since the surface of the rocks has there preserved its distorted aspect, its rugged roughnesses, the sharp edges of the very recent lava flows, it must be that the caving in followed very close upon the emission of the lavas, and that this collapse was sudden. Otherwise atmospheric erosion and marine abrasion would have leveled the inequalities and planed down the entire surface. Let us continue our reasoning: We are here on the line which joins Iceland to the Azores, in the midst of the Atlantic volcanic zone, in the midst of the zone of mobility, of instability, and present volcanism. It would seem to be a fair conclusion, then, that the entire region north of the Azores and perhaps the very region of the Azores, of which they may be only the visible ruins, was very recently submerged, probably during the epoch which the geologists call the present because it is so recent, and which for us, the living beings of to-day, is the same as yesterday.

Now let us see what are the geologic conditions of the Azores. Gagel[1] tells us that this group of nine islands rises out of the Atlantic from depths of 10,945 feet to elevations of 3,250 feet, and in one case even to 8,040 feet above the surface of the sea. There are here no old sedimentary or old eruptive formations and the islands appear to be of very recent volcanic origin. Among the volcanic materials have been found only inclusions of fossiliferous middle Miocene limestone. He concludes that they are volcanic islands of Tertiary age that are made up in the main of trachytic and basaltic lavas, that these have probably built themselves up to elevations of from 16,250 to over 21,125 feet, and that some of these volcanoes have been active during the past four centuries.

If the region of the Azores and that to the north of them for many hundreds of miles had been parts of a great continent now sunk deep into the Atlantic, there should be some evidence of this sinking shown in a well marked elevated sea terrace all along the Atlantic, for it is postulated that Atlantis sank when humanity had attained a high state of civilization; in fact the time when the warriors, according to Plato, came from Atlantis cannot be more ancient than Egyptian history. In other words, Plato's Atlantis must have disappeared not more than 8,000 to 10,000 years ago, for the priests of Egypt told "of a singularly powerful army, an army which came from the Atlantic and which had the effrontery to invade Europe and Asia . . . Later, with great earthquakes and inundations, in a single day and one fatal night, all who had been warriors against you [Athens] were swallowed up. The island of Atlantis disappeared beneath the sea."

The area of land supposed by Termier to have sunk is not less than 40,000 square miles, and if we accept his greater supposition that it included also the region to the north, the mass would be not less than 700 miles long by 300 miles wide, or 210,000 square miles. Now, let us see how much water the sinking of such masses is equal to, with a view of learning how much the eustatic strand-line of all oceans would be lowered. Murray estimates the superficial area of the oceans as about 139,000,000 square miles, and the mean depth as 13,000 feet. Therefore, to sink a mass so small as 40,000 square miles to a depth of 10,000 feet would only lower the general strand-line a little more than three feet. If, however, the greater estimate of 210,000 square miles be taken, then the oceanic level would be reduced about 15 feet and this should show in a well marked terrace all along the Atlantic shores. However, it is not only in the Azores that Termier seeks for Plato's lost land, but in the Canary and Cape Verde Islands as well. In other words, he believes that a continent greater than anything assumed for the Azores has very recently foundered, and therefore we should all the more easily observe an elevated strand-line along the Atlantic shores of North America. It is true that there are at least three Pleistocene elevated terraces recorded in Maryland, the highest and oldest one at 220 feet, known as the Talbot terrace, the middle Wicomico one at 100 feet, and the lowest and youngest at 40 feet, the Sunderland terrace. None of these, however, can have any connection with the foundering of Atlantis, as they are far older in age than Plato's account. On the other hand, these and the other Pleistocene terraces are due not only to isostatic and orogenic factors, but also to the climatic factor, as explained by Barrell.[2] From this we see that if a continent situated in the Atlantic foundered into the depths of this ocean, it must have done so in far more ancient times than those of civilized man. Furthermore, the geology of the Azores shows that these islands are not parts of a foundered continent, but that they are volcanic islands that have arisen above the Atlantic bottom during the latter part of Cenozoic time. On the other hand, we learn from Gagel that five of the islands of the Cape Verde group and three of the Canaries have rocks that are unmistakably like those common to the continents. Taking into consideration also the living plants and animals of these islands, many of which are of European-Mediterranean affinities of late Tertiary time, we see that the evidence appears to indicate clearly that the Cape Verde and Canary Islands are fragments of a greater Africa. It is therefore not to the north of the Pillars of Hercules that we should look for Atlantis, but to the southwest of the rock of Gibraltar.

To follow out another line of evidence, the writer understands petrographers know little from actual observations as to the behavior of flowing lavas under the sea, and whether the cooling phenomena and the formation of vitreous lavas would be the same there as beneath the atmosphere. At least three of them, however, are of the opinion that tachylyte would form equally as readily beneath the sea as on land. In answer to a request for data that might bear on this problem, Dr. A. L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, directed my attention to a recently published paper by Perret.[3] Last year the latter studied the flow of lava descending from the volcano of Stromboli, in Sicily, and entering the sea, and in 1914 a similar occurrence at Sakurashima, Japan. At Stromboli a surface flow was 20 meters wide, and the hot lava "entered the water at an average rate of about 3 cm. per minute." A little distance beyond the actual contact with the water and in "a perfectly calm sea there is rarely a continuous and uniform evolution of vapor. At Sakurashima, on March 12th, 1914, the lava, at one place, was entering a sea as smooth as glass, yet the evolution of steam was spasmodic and resulted in a series of puffs." In regard to the subsurface flow of lava, a condition of greater importance in the present discussion, Perret writes as follows:

At Sakurashima there was a submarine lava flow extending from beneath the eastern lava field for a distance of 2 kilometers along the sea bottom. The lava had a depth of some 75 meters, with 40 meters of water above it . . . The only disturbance visible at the surface was a succession of convection currents in the water, without eruption of gas, and without raising the water temperature above 64° F. at the surface and 72° just over the lava.

He concludes "that a flowing lava may exist in contact with water without the disintegration of either, thanks to the formation of a protective sheath, and this fact helps us to understand the quiet growth of submarine volcanoes. In such cases the only surface commotion need be that due to true gas emission at the central vent. In point of fact, a sub-aqueous lava stream comports itself more decorously than a similar sub-aerial one." This is due to an important fact, namely, that even if the protective cooled sheath is broken in places "and a little water enter and be vaporized in the act of sheathing the raw places . . . that which is thus evolved is simply the vapor of water, and this, in the presence of water in mass, condenses to water again—there is nothing to reach the surface and cause ebullition."

Doctor Day in the letter to me mentioned above, dated November 27th, 1916, comments on Termier's conclusion and the observations of Perret as follows:

I have just read Professor Termier's interesting speculation entitled "Atlantis" and must confess that I find nothing in my experience with which to support his views. In the forthcoming number of the *American Journal of Science* you will find an article by Perret [the one reviewed above] who is one of the most accurate observers of volcano phenomena with whom I ever came in contact. In this article he records in unmistakable terms that there is no essential difference in the behavior of a sub-aqueous and a sub-aerial flow other than that which may be exerted by the superimposed hydrostatic pressure. From such experience as we have gathered in this laboratory, hydrostatic pressure can have no other effect than to raise the melting temperature ten or twenty degrees per thousand atmospheres, that is, one or two per cent, and this factor must therefore be ac-

*A paper published in the *Proceedings of the National Academy of Sciences*.

[1] Gagel, C., *Handbuch der Regionalen Geologie*, 7, Pt. 10, Heidelberg, 1910.

[2] Barrell, J., *Amer. J. Sci., New Haven, Conn.*, (Ser. 4), 40, 1915 (1-22). Also see Wright, W. B., *The Quaternary Ice Age*, London, 1914, chaps. 16 and 18; and Goldthwait, J. W., *Amer. J. Sci., New Haven, Conn.*, (Ser. 4), 32, 1911 (291-317).

[3] Perret, F. A., *Amer. J. Sci., New Haven, Conn*, (Ser. 4), 42, 1916 (443-463).

counted comparatively insignificant in determining solidification. It is conceivable that great hydrostatic pressure might have the effect of preventing the escape of the volatile ingredients contained in a sub-aqueous lava flow and so facilitate crystallization. It is our experience that a very small quantity of such ingredients has enormously greater influence in determining crystallization than a very large hydrostatic pressure alone. It might therefore follow that the pressure operating in this indirect manner might serve to keep volatile ingredients "on the job," so to speak, which would otherwise escape and so promote crystallization in a mixture which would otherwise tend to cool in vitreous form. Beyond this possibility I can conceive of no basis in present experience for the assertion which Termier has made. In general, silicate mixtures which crystallize with difficulty will form glass if cooled quickly whether under pressure or not—the pressure apparently being the least important factor in the situation. Similar mixtures which crystallize readily can with great difficulty be cooled quickly enough to prevent crystallization, and here again the factor of pressure is relatively insignificant.

You may recall a paper by Johnston two or three years ago in which he showed plainly and unmistakably that in general small changes of temperature or concentration would have greater effect in determining the resulting solid form than a thousand atmospheres of pressure. This conclusion is in a sense obvious, for if a thousand atmospheres will produce no more than ten or twenty degrees effect on the melting temperature, then obviously ten or twenty degrees temperature change in this temperature region will be its equivalent. In the same sense a one or two per cent admixture of one of the volatile ingredients will produce several tens of degrees lowering of the melting point of the solution in this temperature region. These considerations are perfectly general and apply without reservation to the condition of things which Termier is discussing. I am therefore disinclined to give any weight to the evidence which he adduces in proof of the contention that vitreous basalts could not have formed at depth as well as anywhere.

This paper has also been read by Prof. L. V. Pirsson, and he makes the following comments in regard to the formation of tachylytes:

Whether a magma will solidify in a vitreous or a crystalline condition appears to be much more due to temperature than to pressure. The latter, in the quantities which we have to deal with in the superficial crust of the earth, seems relatively negligible compared with very moderate changes of temperature. If the change of temperature of a basaltic magma on attaining a sub-aerial surface is sufficient to cause it to solidify as a glass, or tachylyte, as we know it may, there seems no good reason why a basalt magma issuing into cold water on the sea-floor might not be similarly affected and have an upper glassy crust. Such a glassy skin on the lava would seem an even more natural result from the melt being plunged into cold water than if it cooled in the air, the pressure of the depth of water being a minor consideration compared with the sudden change of temperature. The experience of mankind from remote ages has taught that the quickest and most convenient way of suddenly cooling a heated material is to plunge it into cold water.

That basaltic glasses, or tachylytes, are not formed solely under atmospheric conditions is shown also by the fact that they have been found as the selvage edges of intrusive rocks, in dikes, and in intrusive sheets, in Finland, Sweden, Connecticut, and elsewhere. These glassy sulbands are now revealed to us only after prolonged erosion, and the geologic evidence would appear to indicate that they were probably formed under greater pressures than would be produced by the weight of the water of the ocean. It was the sudden chilling, produced by the contact with cold rocks, which forced the glass to form in spite of the pressure.

In the light of petrographic experience it does not seem that the generalization of Professor Termier is well founded. The fact of dredging glass splinters from oceanic depths in a volcanic region can hardly be held in itself as a proof of profound subsidence of such an area from sub-aerial conditions.

The conclusions from these various studies are (1) that the Azores are volcanic islands and are not the remnants of a more or less large continental mass, for they are not composed of rocks seen on the continents; (2) that the tachylytes dredged up from the Atlantic to the north of the Azores were in all probabliity formed where they are now, at the bottom of the ocean; and (3) that there are no known geologic data that prove or even help to prove the existence of Plato's Atlantis in historic times.

The greater question, was Africa ever united to South America, is being answered by biologists and geologists, "yes" and "no." The writer, however, believes in this connection previous to the Tertiary and thinks that the down-breaking of western Gondwana began in the late Lower Cretaceous, with complete severance long before the close of Eocene time, for marine strata of this age are general along the western border of Africa. On the other hand, if this land bridge had continued unbroken into Tertiary time, even only as late as the later Eocene, then certainly the wonderful fossil mammalian faunas of Argentina should have revealed many and unmistakable African links. The African affinities in the ancient South American mammalian faunas are, however, so slight as to give but a very limited support to the theory that Gondwana was still in existence in early Tertiary time, and none at all to the theory that the South Atlantic bridge was present even in the Miocene.

A Ten-Inch Diffraction Grating*

By A. A. Michelson, Ryerson Physical Laboratory, Etc.

The principal element in the efficiency of any spectroscopic appliance is its resolving power—that is, the power to separate spectral lines. The limit of resolution is the ratio of the smallest difference of wave-length just discernable to the mean wave-length of the pair or group. If a prism can just separate or resolve the double yellow line of sodium its limit of resolution will be (5896-5890)/5893 or approximately one one-thousandth, and the resolving power is called one thousand.

Until Fraunhofer (1821) showed that light could be analyzed into its constituent colors by diffraction gratings these analyses were effected by prisms the resolving power of which has been gradually increased to about thirty thousand. This limit was equaled if not surpassed by the excellent gratings of Rutherford of New York, ruled by a diamond point on speculum metal, with something like 20,000 lines, with spacing of 500 to 1,000 lines to the millimeter. These were superseded by the superb gratings of Rowland with something over one hundred thousand lines, and with a resolving power of 150,000.

The theoretical resolving power of a grating is given as was first shown by Lord Rayleigh by the formula $R=mn$, in which n is the total number of lines, and m the order of the spectrum. An equivalent expression is furnished by $R=\frac{l}{\lambda}(\sin i+\sin \theta)$, where l is the total length of the ruled surface, λ the wave-length of the light, i the angle of incidence, and θ the angle of diffraction; and the maximum resolving power which a grating can have is that corresponding to i and θ each equal to 90° which gives $R=2l/\lambda$, that is twice the number of light waves in the entire length of the ruled surface.

This shows that neither the closeness of the rulings nor their total number determine this theoretical limit, and emphasizes the importance of a large ruled space.

This theoretical limit can be reached, however, only on the condition of an extraordinary degree of accuracy in the spacing of the lines. Several methods for securing this degree of accuracy have been attempted but none has proved as effective as the screw. This must be of uniform pitch throughout and the periodic errors must be extremely small.

For a short screw for example, one sufficient for a grating two inches in length, the problem is not very difficult but as the length of the screw increases the difficulty increases in much more rapid proportion. It was solved by Rowland in something over two years.

Since this time many problems have arisen which demanded a higher resolving power than even these gratings could furnish. Among these is the resolution of doubles and groups of lines whose complexity was unsuspected until revealed by the interferometer and amply verified by subsequent observations by the echelon and other methods.

Others that may be mentioned in this connection are the study of the distribution of intensities within the spectral "lines;" their broadening and displacement with temperature and pressure; the effect of magnetic and electric fields, and the measurement of motions in the line of sight, as revealed by corresponding displacement of the spectral lines in consequence of the Doppler effect.

All of these have been attacked with considerable success by observations with the echelon, the interferometer and the plane-parallel plate. These methods have a very high resolving power, but labor under the serious disadvantage that adjacent succeeding spectra overlap making it difficult to interpret the results with certainty.

Some twelve years ago the construction of a ruling engine was undertaken with the hope of ruling gratings of fourteen inches—for which a screw of something over twenty inches is necessary. This screw was cut in a specially corrected lathe so that the original errors were not very large, and these were reduced by long attrition with very fine material until it was judged that the residual errors were sufficiently small to be automatically corrected during the process of ruling.

The principal claim to novelty of treatment of the problem lies in the application of interference method to the measurement and correction of these residual errors.

For this purpose one of the interferometer mirrors is fixed to the grating carriage, while a standard, consisting of two mirrors at a fixed distance apart, is attached to an auxiliary carriage. When the adjustment is correct for the front surface of the standard, interference fringes appear. The grating carriage is now moved through the length of the standard (one-tenth of a millimeter if the periodic error is to be investigated; ten or more millimeters if the error of run is to be determined) when the interference fringes appear on the rear surface. This operation is repeated, the difference from exact coincidence of the central (achromatic) fringe with a fiducial mark being measured at each step in tenths of a fringe (twentieths fo a light-wave). As a whole fringe corresponds to one hundred-thousandth of an inch, the measurement is correct to within a millionth of an inch.

The corresponding correction for periodic errors is transferred to the worm wheel which turns the screw; and for errors of run to the nut which moves the carriage. In this way the final errors have been almost completely eliminated and the resulting gratings have very nearly realized their theoretical efficiency.

A number of minor points may be mentioned which have contributed to the success of the undertaking.

(*a*) The ways which guide the grating carriage as well as those which control the motion of the ruling diamond must be very true; and these were straightened by application of an auto-collimating device which made the deviation from a straight line less than a second of arc.

(*b*) The friction of the grating carriage on the ways was diminished to about one-tenth of that due to the weight (which may amount to twenty to forty pounds) by floating on mercury.

(*c*) The longitudinal motion of the screw was prevented by allowing its spherically rounded end to rest against an optically plane surface of diamond which could be adjusted normal to the axis of the screw.

(*d*) The screw was turned by a worm wheel (instead of pawl and rachet) which permits a simple and effective correction of the periodic errors of the screw throughout its whole length.

(*e*) A correcting device which eliminates periodic errors of higher orders.

(*f*) It may be added that the nut which actuates the carriage had bearing surfaces of soft metal (tin) instead of wood, as in preceding machines. It was not found necessary to unclamp the nut in bringing it back to the starting point.

Finally it may be noted that instead of attempting to eliminate the errors of the screw—by long continued grinding which inevitably leads to a rounding of the threads—it has been the main object to make these errors conveniently small; but especially to make them constant—for on this constancy depends the possibility of automatic correction.

Doubtless the possibility of ruling a perfect grating by means of the light-waves of a homogeneous source has occurred to many—and indeed this was one of the methods first attempted.

It may still prove entirely feasible—and is still held in reserve if serious difficulty is encountered in an attempt now in progress to produce gratings of twenty-inches or more. Such a method may be made partly or perhaps completely automatic, and would be independent of screws or other instrumental appliances.

It may be pointed out that an even simpler and more direct application of light waves from a homogeneous source is theoretically possible and perhaps experimentally realizable.

If a point source of such radiations sends its light-waves to a collimating lens and the resulting plane waves are reflected at normal incidence from a plane surface, stationary waves will be set up as in the Lippman plates; these will impress an inclined photographic plate with parallel lines as in the experiment of Wiener; and the only limit to the resolving power of the resulting grating is that which depends on the degree of homogeneity of the light used. As some of the constituents of the radiations of mercury have been shown to be capable of interfering with difference of path of over a million waves, such a grating would have a resolving power exceeding a million.

This investigation has had assistance from the Bache Fund of the National Academy of Science, from the Carnegie Institution, and from the University of Chicago. In addition to the grateful acknowledgment to these institutions I would add my high appreciation of the faithful services rendered by Messrs. Julius Pearson and Fred Pearson.

*From a paper published in the Proceedings of the National Academy of Sciences.

Double keyboard machine with upper and lower case letters requiring no shift key. This assembly is for not more than two copies. No carbon paper is required, as a typewriter ribbon serves the purpose instead. The top and bottom edge of the sheets that are torn off are straight and true enough for most purposes. They can, of course, be trimmed with shears or cutters if desired, but when it is understood that the torn edge is the handmark of crippled employment it will be rather desirable than otherwise. The rolls of paper can pe printed with a letter-head at the top and guide marks for trimming sheets to exact size if desired. If greater economy of paper is desired, the printing can be put in repetitive form in the left-hand margin and the paper can then be torn off just below the last line, regardless of the length of the sheet.

The Problem of the Crippled Soldier*

How to Put Him On the Pay Roll

By Frank B. Gilbreth, Am. Soc. M. E., and Lillian M. Gilbreth, Ph.D.

There are few problems before the world to-day more important than that of putting the Crippled Soldier back on the pay roll. If we broaden the term to include industrial cripples, we have a problem that affects all countries and all times. Because the war cripple appeals to popular sympathy, we are all vitally interested to-day in studying and solving this acutes apect of the problem, but our results are usable in the field of re-education of the injured of all types.

The problem of the Crippled Soldier is assuming greater proportions every day. The first stage of the solution of the problem is past: that is to say, in all countries has come a realization of the seriousness of the conditions that exist, and of the necessity of doing something to better the condition immediately. With the knowledge of the seriousness of the condition has come a growing interest in the whole subject, and a desire to coöperate in putting these cripples on a self-supporting, happy and efficient basis as rapidly as possible.

There are those who object to putting the cripple on the pay roll, feeling that he has done his part, and that it is the duty of Society to support him the rest of his life. There are many answers to this objection. It is a question whether Society can afford to support such an enormous number of non-producers, no matter how just their claim to support. Partial support may be possible, time alone can determine this.

The real answer to the objection is that the health and happiness of the cripple himself demand that he be kept busy from the earliest stage in his recovery period that he is really able to work, and that he be re-educated at the earliest possible moment. Reports of convalescents of all the warring countries show that the greatest problem is to persuade the man that life is worth living even in his maimed condition, and that he is still needed to do his part in the world's work. The injured man must be made to feel that he is not an object of charity, or even a pensioner, but that he is a handicapped contestant in the world of active people, and that it is a sporting event what and how much he can do.

All who have taken part in or investigated work with cripples agree that it is essential that activity be attempted as soon as possible, the only question is, shall the activity be really productive or not. Surely in these times this is no question at all, and it is our duty to furnish real work to the cripple, work that he can do efficiently, and that will bring him returns in money, in satisfaction, in self-respect, and in the happiness that results from attaining these.

In order to do this, we must:

1.—Find types of work that a cripple can do.

2.—Demonstrate to the cripple the advantages of working.

3.—Find the type of work that the cripple can do and desires to do.

4.—Adjust the cripple to the work.

5.—Teach the cripple to do the work.

6.—Persuade the uninjured man that it is hardly respectable to do work that can be done by a cripple.

These are all parts of the Crippled Soldier work, but it is not necessary to complete one part in order to start on another, in fact, all six of these are being done now.

Single keyboard typewriting machine for any number of sheets up to four. No carbon paper is required, as ribbons serve the purpose, thus reducing the number of motions to a minimum. The magazine holding a week's supply of paper is attached to, and travels with, the carriage. The sheets may be torn off separately, or all at once, against a sharp, straight edge. This single keyboard machine can be used with capitals and small letters, even by a one-fingered typist by locking the shift key down when a capital is required; but much greater speed can be attained if capitals only are used, though this retards the speed of reading of most people, slightly.

We find work that cripples can do in two ways—first by collecting records of cases where cripples have done various things, second by studying the work of the injured workers, in order to find what members are used, and how the work may be reassigned to other members. This we do through the micromotion film and the Simultaneous Motion Cycle Chart, not to be described here, since they have been described already in available papers.[1]

We demonstrate to the cripple the possibilities and the advantages of working by showing him these records of both types. It should be noted here that the cripples are only too happy to be helped to be useful, if the re-education is begun soon enough, before they have to contend with the bad advice of the ignorant, well meaning friends, and the difficulties of overcoming habits of idleness. This is really understating the facts. We receive constantly pitiful news of the desperate desire of the injured to be helped back to activity, and of the danger of the depression that inevitably results if hopes of re-education are not supplied immediately.

Finding the type of work that the particular cripple desires to do and can be fitted to do is largely a matter of tests that are at present being formulated and tried.

Adjusting the cripple to the work is done by two methods. These will be discussed in detail later.

The teaching is done through all the ordinary teaching devices, supplemented not only by micromotion films that show how the work is done and how long it takes to do it by elements and as a whole, but also by cyclegraphs, motion models, stereoscopic photographs and charts.

The uninjured man need not be made the subject of a harangue on leaving such work as he can do to the cripple. The average worker teaches the world the meaning of true brotherliness, and will be more than ready to do his part in adjusting the industrial world to accommodate the new type of worker, when he realizes the need.

We shall now discuss the problem of adapting the cripple to the work in some detail, as it is one toward whose solution we can all contribute. There are two distinct methods of attacking the problem, both valuable, the two being supplementary to one another.

The European method is well exemplified by the work of the famous French scientist, Dr. Jules Amar, who, in typical papers, considers the device or contrivance that the cripple is to use as the fixed element, and adapts and equips each cripple so that he can use the devices of his trade, or of the new work that he has chosen to do.

The typical American attitude is, perhaps, exemplified by our work in considering the cripple as the fixed element, and adapting the device and method to the individual cripple who is to use it. It is but natural that the first method, that of the genius, Amar, should be used abroad, where many of the labor saving devices in use come from America, or some other foreign country, and can not be easily adapted. It is as natural that our methods should be in use here, where the devices are more easily changed, to suit individual workers, by the original maker of the machines.

As an example of the two methods, let us take the case

*Presented at a Conference of The Economic Psychology Association, New York, Jan. 26-27, 1917.

[1] A paper read before the Am. Soc. of Mechanical Engineers.

Phantom picture made by double exposure, showing the total range of movement of the head and back, of a one-armed typist, necessary to operate this combination after a month's supply of paper providing for four copies has once been inserted for him. The shift key for making either capitals or small letters can be operated by either foot or knee, or, if the typist has no limbs at all, except one finger or one thumb, the shift key can be locked down with one motion, long enough to make the capital and released again for the small letters. To attain still greater speed the shift key may remain in such locked position, thus making all letters capitals.

This machine is a combined typewriter and addition and subtraction machine. The same motion that presses the key to print the figure operates the addition and subtraction machine. Therefore, this combination offers to the legless, one-armed, one-eyed, deaf, stiff backed cripple a chance to get back on the payroll, regardless of what he may also get as a pension.

Some idea of the distance of motion can be obtained from the cross sectioned background, the lines of which are four inches, or approximately ten centimeters apart.

of the cripple to be trained to be a typist. The Amar Method is demonstrated plainly by the illustration herein included, furnished us through the courtesy of Prof. Amar himself, whose coöperation on work for the Crippled Soldiers we are pleased to acknowledge. The other method we will describe in detail, hoping to arouse still further coöperation in this work in this country. Prof. Amar's illustration shows a one-armed man operating the typewriter. We will illustrate the same subject, and device as attacked by the other method, by considering the cripple as the fixed element. In considering any type of activity to which it is proposed to introduce the cripple, we first analyze this activity from the motion study standpoint, in order to find exactly what motions are required to perform the activity, and in what way these motions may be adapted to the available, or remaining, capable members of the cripple's working anatomy, or eliminated by altering the device or machine itself.

Through a careful examination of the motions of many of the world's most expert typists, we found many interesting facts not generally known; for example, that the time required by the usual commercial typist to take out a finished sheet of paper and insert another in a position exactly level in the typewriter was about ten seconds. The time required to do this same work by Miss Hortense Stollnitz, the recent winner of the International Amateur Championship, is less than three seconds, while Miss Anna Gold, who won the National Amateur Championship, requires still less time. Our first thought, then, naturally, was to find and transfer the activity requisite for that shortest, most efficient method to the work method of the cripple to operate the machine. We found that Mr. Casey, the one-armed Secretary to the Mayor of Boston, could, with a simple device of his own invention insert the paper with much skill, and that he operated the shift keys of his Oliver Typewriter by means of foot pedals of his own design.

At this point we found, however, a device that handled the paper in such a manner that all motions of inserting and taking out were eliminated from the ordinary work of the typist. With the coöperation of the leading makers of typewriters, such as the Remington, the Monarch, and the Smith-Premier Typewriters, and particularly of Mr. George W. Dickerman, the devices were sent to our Motion Study Laboratory, where the motions of the machine and its operator were analyzed, measured, and charted. How successful the results were is shown by the illustrations herein included. By means of this device, the one-armed soldier or industrial cripple can remove his paper and be ready with a new sheet inserted in place in two seconds.

When one original and several duplicates are made by the old method, the time required is, of course, longer for the commercial typist, because of the time and care required to handle the carbon paper and to keep the sheets of paper even and smooth. With the typewriting machine arranged for the cripple it takes no longer to handle two, three or four copies than it does to handle the single copy, because the duplicating is done by a permanent ribbon attached to the machine, and the trouble of handling the carbon paper is entirely done away with. If the rolls are kept free from the machine and hung on the wall, or other high support, they can be of any desired diameter, permitting a month's supply of paper if desired. The paper when attached to the machine is in rolls four inches in diameter. The process of tearing the paper into sheets of desired lengths is very simple, and can be done with one motion. The top and bottom edges of these torn sheets show an edge not quite as straight as if cut with the shears, but as straight as any paper torn against the sharp edge of a straight ruler.

Remarkable artificial articulated hand, introduced by Professor Amar.

Another example of the use of an existing device to facilitate the work of typing for a cripple is that of the double bank of keys such as exist in the Smith-Premier Typewriter, and the use of a machine having all capitals and a single bank of keys as with the Remington or Monarch. By this means the motions of the shift keys are entirely dispensed with, and a legless, one-handed typist is enabled to equal the output of many of the commercial typists who are using but two of their ten fingers to-day; and a cripple with but a single finger can earn a living. We have also found dictating machines of use in decreasing the number of variables against which the typist works. When provided with a dictating machine, a typewriter requiring no shift key action and with the rolls of paper properly attached, a willing one-handed worker can compete successfully with the average stenographer typist with the old equipment, and perhaps in some cases be able to earn more money than before being crippled. He can, in a small office, handle successfully dictating machine, typewriter, adding machine and telephone.

This use of, or adaptation of, existing devices by no means does away with the necessity of the most careful motion study and fatigue study of the operation. It is only through these that one is enabled to classify completely the motions involved, and to discover which ones of these can be handed over to available, securable or inventable devices.

We have so far found all manufacturers of devices approached more than willing to adapt their work to the requirements of those who are maimed and crippled. We hope by offering this paper to arouse still further coöperation in the makers and users of devices, that they may think in terms of cripples during the inventing, manufacturing and using periods.

This branch of the work, like all the other branches, demands the most careful investigation of the mental as well as of the physical side. There are certain types that will respond quickest to attempts to use the regulation equipment, and will be willing to adapt themselves, even to their own discomfort, in order to use it. Their are others who feel that it is their right to have all mechanical aids at their services. There are some who find artificial limbs, and especially mechanical limbs, helpful and interesting. There are others who have no use for any such devices, and who prefer to show their adroitness by doing, with their limited equipment, all or nearly all that the ordinary uninjured man can do. Each individual must be studied, and the proper method of treatment applied.

But it is the work of all of us to supply the data with which the experts will work. The individual histories of cases where cripples have been enabled to cope successfully with their handicaps must be collected. The data must then be compiled, properly classified and cross-indexed, and incorporated into a series of books, copies of which should be put into every large library in the world. This work would eventually pay for its cost of compiling and distributing, and no one can estimate the good that would be done by having every cripple feel that he had actually books of cases of men injured like himself to refer to for help and encouragement. The histories should be not only of those who have been recently crippled, but also of old cases of the handicapped who became skilled. They should also include those born handicapped, as well as those injured later.

The great need is that everyone shall realize that there is a part in the work for him. It is the work of the psychologist, of the economist, of the industrial expert—True! It is just as much the work of every man, woman and child in the community. It is active, practical interested coöperation that it needed—and it is needed NOW!

Iron for Electrical Machinery

It is reported that electrolitic iron, in the shape of tubes and sheets, is being produced in France, which is very pure, and consequently valuable for electrical apparatus. Iron pipe is made by using a rod as a core.

The Limitations of Stained Glass*

A Comparison of Ancient and Modern Methods

By R. C. Bayne

THE study of old glass—that is to say, more particularly of the thirteenth, fourteenth, and fifteenth centuries—while being most helpful and, indeed, necessary to the student, is such an interesting and fascinating pursuit that many have been obsessed by it, and have turned "old glass" into such a fetish that they insist that the craftsmen of to-day should imitate and even copy the works they admire so much, not only in general treatment, but also in drawing, color, and method of painting.

The attempt to conform to this limitation has been very largely the cause of the sham mediævalism that is still to be found in much modern glass, and was almost invariable in early Victorian, and accounted in part for its utter lack of character.

There are certain limitations the student must bear in mind for the production of really excellent work, and these may roughly be placed under three heads. The first is common to every form of art and craft and is good taste; the second is that glass being a form of decoration, must abide by the restrictions that word entails; and the third is the limitation imposed by a frank use and recognition of its materials—lead and glass.

There is one important fact that many writers on early glass omit to mention—*i. e.*, that none of the ancient glass is now in the condition in which it left the hands of its producer; they voice their great appreciation of it not as it was, but as it is, and seem to forget that nature has played no mean part in its production. She has painted it by decay, with a very lavish hand, until what at first must have been thin and garish to our modern taste has become a beautiful and deeply toned harmony. If the critics incited the student to imitate the tone of old glass as we now see it, there would be little to quarrel with them about; but while they extol it as it is they seek to limit us to producing something much more like what it originally was; and, unfortunately for us, there is no example left in anything like perfect or new condition, or one may venture to think we should not hear quite so much on the subject.

Unfortunately, in these days there is no living style of architecture. Glass being a form of decoration, and hence of necessity merely a handmaid of architecture, is in much the same quandary. It necessarily follows that so far as ornamental forms are concerned it must follow the general characteristics of the building in which it is to be placed, or it may tend to spoil instead of decorate. But in respect of the figures, costumes, and general treatment, let the art live, and living progress. Present-day knowledge is greater in every way than that possessed by the early craftsman; it would surely be wrong to stultify it by not putting it to practical application.

It would be as reasonable to have the Battle of the Somme depicted in our illustrated papers after the manner of Durer, with our troops in plate armor firing arquebuses and mediæval cannon, as to depict our figures, no matter in what age they lived, in thirteenth, fourteenth, or fifteenth century costume merely to suit the style of the building.

Yet numerous experts insist on this kind of thing being done. They are designing, say, in fifteenth century style, and therefore whether their subject be St. David (fifth century), St. Augustine (sixth century), or William of Wykeham (fourteenth century), they represent them in precisely the same costume, with bishops' vestments and tall mitres. The ancient craftsman knew no better; he depicted his figures in the costumes he saw used in everyday life. Modern research has given us greater knowledge, and we know that while the mitre is correct for William of Wykeham, it was unknown in the days of St. Augustine, as it did not come into use until the twelfth century.

Or, again, take the Roman soldiers guarding our Lord's tomb; are we to represent them in fifteenth century plate armor? I contend it would be quite as justifiable to imitate the practice of the ancients, go to our own everyday costume, and clothe them in khaki.

Surely the use of correct costume can but give an added interest; and the sense of style can still be kept, if desired, by general treatment.

Research has endowed us with many other advantages besides the knowledge of correct costumes, and it is our duty to make full use of them. We have the diamond and the even more modern steel wheel with which to cut our glass, in place of having to break it by heat roughly to size and then groze it to correct shape with pliers, as had to be done in times past. In place of the very limited palette of the ancient craftsman, which consisted of but two or, at the most, three tints of each primary color, we have to-day glass of every conceivable tint and hue, primary, secondary, and tertiary, each tint graduated from dark to light, and often with two colors of different shades blended or streaked on a sheet; and yet some would confine us to the use of only those colors found in old glass. There is a popular misconception, constantly repeated in the press, that stained glass is a lost art, and the remark is intended more particularly to refer to color. It may be said without fear of contradiction that there is no color found in old glass that cannot be obtained to-day. A paragraph appeared in most of the papers a few weeks back to the effect that at last the secret of making ruby glass had been discovered. Certain fragments from the shattered windows of Rheims Cathedral having been examined and analyzed, it had been found that ruby was made by flashing the color on a deeply toned white. Now certainly for the past thirty years ruby has been made in this manner, in addition to being flashed on pure white, blue, yellow, and deep green. Old works demonstrate the toning and darkening produced by corrosion amounting in some places to actual blackening. In the case of color this corrosion has the effect of reducing their brilliancy; thus primary colors may in time attain to secondary or even tertiary effects, and in this way old glass has acquired a greater range of color than it possessed when first executed; and, some parts having resisted the destroying hand of time better than others, a jewelled and brilliant effect is thus obtained by force of contrast. In these strenuous days we are not content to wait for a few centuries for our work to tone or we might make our windows with the glasses used by our predecessors. Neither can we well employ so great an amount of pigment as would be necessary to produce the effect of great age on the brightest glasses; we therefore make use in some portions of sharp colors, in others those of more neutral tint, and then tone the whole by a freer employment of pigment in painting in our details than was the custom in earlier ages; and without this free use of pigment it will be found impossible to obtain the mellow unity so much admired.

We are told that this use of pigment is wrong, and that we should leave our glass in its purity. Some have attempted to put this theory into practice; and the very latest thing, in fact an example of "Futurism" in glass, is to be seen in a window recently placed at the west end of St. Mary's, Slough. This work was much extolled in the "Observer" as the finest thing done in the art since the seventeenth century. It certainly conforms to all the limitations ever imposed except that of color, inasmuch as it is pure glass and lead without pigment, if not without design of any kind. The newspaper's art critic, however, stated that the theme was Adam and Eve in the Garden of Eden, and particularly called attention to the beauty of Eve's hair and to the theme of the Serpent running through the whole composition.

To some eyes, doubtless owing to lack of soul, it appeared to be merely a meaningless jumble of full, bright, and, indeed, garish color. As a proof of its excellence it was specially remarked that it completely killed the east window in the same church executed a few years earlier and a good example of a certain style of modern glass. Kill it it certainly does, and so would a bright patchwork quilt kill any old painting however magnificent alongside of which it might be hung. Time may work wonders on glass such as this, though even that is doubtful, as, apart from dust and dirt, there is not likely to be anything approaching the decay caused by atmospheric and other forces on ancient glass, owing to the much greater hardness of the modern product.

In the sixteenth century glass departed rather rapidly from the customs of the earlier periods; and, though much of the execution and drawing was admirable, the designers were not so careful in keeping their work in harmony with the architecture; in fact, they often ignored altogether the shape of the lights they were filling. The mullions were ignored, a figure might extend over three of the lights, the body in one, an arm in another, or a leg protruding into a third. Such treatment violates the idea of decoration, inasmuch as it takes no note of the architect's design and is uncomfortable to look upon; it produces a feeling that the figures are too big for the window. During that century backgrounds became much more elaborate and a larger quantity of pigment was used, the flesh being in some cases very carefully and deeply painted, and in this respect they more nearly conform to modern practice.

Those who deprecate elaborate painting tell us that windows are primarily intended to admit light. Such a statement cannot be denied. But does it necessarily follow that the argument applies to those made of stained glass? If the greatest amount of light possible is required, plain glass would better suit the requirement. Undoubtedly there is a temptation in making a window to make it too dark, as the darker it is the richer and more beautiful is the color effect that can be obtained; but most of us will admit that a dim religious light can be overdone. Then again, colored windows are intended to teach and elevate the thoughts of the beholder; and it follows that the nearer the costume is to truth, and the closer the subjects keep to the text, the more interesting and instructive they become.

The ancient treatment of, say, "The Crucifixion," on a merely diapered ground, or with a screen at the back of the figure, is excellent as a decorative effect; but can we not render the subject much more interesting and more illustrative of the story by suggesting in the background the "green hill without a city wall"? And what more decorative objects can one have than sky and trees, both of which lend themselves to the cutting up of the surface, which is so essential in glass-work, not only for the production of jewelled effects by the use of broken color, but also for strong constructional work in the shape of lead? Big masses of plain color are not pleasing in this art, and should be avoided.

Sky to some may suggest blue, but it can be made of any color except green, red, purple, yellow, and white or combinations of them being all equally effective if properly treated; trees also may be practically of any color that is required in the scheme.

Single-figure compositions also can be made much less monotonous by the introduction of a scene from the life of the saint in the background as, for example, a figure of St. Martin might have as background the incident of his dividing his cloak with the beggar. Treatment such as this adds a sense of mystery, and necessitates a more careful examination to take in details not grasped at the first glance.

Purely natural effects, aerial perspective is fortunately impossible in glass; leads will assert themselves and cannot be melted into the dim distance.

There is, however, one form of glass-work practised in the sixteenth and seventeenth centuries the secret of which is to some extent lost—namely, the process of enamelling, which consists of burning on to white or colored glass of vitreous enamels. This process has been used in modern times, but the enamels are of nothing like so permanent a nature as those found in early examples, neither are they so transparent. Speaking broadly, it is perhaps a blessing that the method of making permanent enamels has never been rediscovered. What a temptation it would be to many artists to forsake the true tenets of stained glass and endeavor to produce purely pictorial effects on big pieces of glass by the use of enamels. There are some good-sized examples of enamelled work to be seen in the chapel of Peterhouse College, Cambridge; the windows were exhibited in the '62 Exhibition, and have been preserved from decay by covering them both inside and out with plate glass. Beautifully drawn and painted, with cast shadows and reflected lights, they are ex-

*Abstract of a Paper read before the Institute of British Decorators by Mr. R. C. Bayne.

tremely pleasing to the average non-technical or, shall we say, uneducated beholder; but to the initiated their lack of decorative feeling, total absence of sparkle, and careful avoidance of the limitations of the material render them unworthy to be spoken of as stained glass, their whole appearance being that of a transparent oil painting.

There is but one permanent enamel in general employment to-day, a blue; this is useful particularly in small heraldic works. There is no doubt other enamels would be of service, providing they were put to legitimate uses and that the temptation to misuse them was carefully avoided.

Leads may be considered from two points of view: as a strengthening subject not alone does it add to the structural durability of our windows, but gives them greater decorative quality and force.

The public often say, "What a pity it is you have to employ all these leads in the window; how much better they would look without them!" Now the truth is the exact opposite of that. The feeling of strength and character added by the leads is almost inconceivable. They help largely to give that decorative feeling that is so essential; cross-leads also give a sense of flatness of field which is most desirable in this art; and it will be found that the more they are used in reason the better is the effect.

As to the method of production of windows, we hear a great deal said nowadays about commercialism. All art must have its commercial side. Artists expect or at least hope to live by their work; but the term is generally used to express contempt for "firms"—that is to say, the association of several persons together for the better, and possibly cheaper, production of their work.

It is contended that the artist should not only design, draw, and superintend the work, but that he should personally cut the glass, paint, fire, and glaze it. Why not also expect him to make the glass, lead, and pigments to be used? Let us consider for a moment what such a requirement really means. Probably all know how long it takes, given talent, to design and draw respectably: shall we put it at seven years? To cut and glaze so that the windows shall be sound and watertight will probably take the craftsman (allowing for superior intelligence) another three years. And to learn the technicalities of tracing and painting two more would be little enough time.

What was the practice of our forerunners? Did not the great artists themselves have their "schools"—namely, numerous pupils working with them and for them? And there is evidence from the registers of many cathedrals and churches that stained glass was always done by a combination of men, draughtsmen, painters, and glaziers.

There are several advantages in work being done by schools, or their modern equivalent "firms." Among them are equality of production and the carrying on of tradition, and the larger stock of materials that can be kept from which to choose what is required for any particular purpose. Again, we seldom find all the talents united in one person, and a combination may ofttimes produce a much finer result than can be hoped for from the work of an individual.

A designer may have novel ideas without being a fine draughtsman. A fine sense of draughtsmanship is often found without a good eye for color, the great joy and beauty of glass. After all, what really counts is the excellence of the finished product, and the school or firm system of production ensures, to some extent, a patron getting what he requires, as the peculiar characteristics by which the work of each is recognized are kept fairly constant, great changes only coming with long lapses of time.

There is one other advantage of combination that one might mention, and that is what is known colloquially as "the fresh eye." Those who do any drawing have doubtless known what it is to feel satisfied with a particular bit of work, after perhaps having taken greater pains than usual; and yet a friend has pointed out some faults, very unreasonably it may seem at the time. Probably you have placed the drawing on one side and forgotten it, and after six months or so have come across it and felt horrified that you could have made such flagrant errors—those your friend had previously pointed out to you—and the quality of the drawing goes down very much in your estimation. It simply means that you have acquired "the fresh eye" so far as that particular drawing is concerned. So in a combination there are plenty of "fresh eyes," and errors stand a very excellent chance of being observed and corrected.

While it is not necessary for the designer of glass to cut and glaze his own work, he certainly should have a thorough technical knowledge of how both processes are carried out, and what can and cannot be conveniently executed. This knowledge can be and is acquired by constantly seeing the work in progress.

To sum up, let the student carefully study glass of all ages and styles, look out for the good and beautiful in each, at the same time note carefully what is defective or unpleasing. Having learned these lessons, let him endeavor, avoiding false shibboleths and eccentricities, to move forward slowly but surely, guided but not enslaved by the traditions of the past.

Then will come real progress in this beautiful craft, which revels in rich sonorous color, the thing which, as a nation, we most lack and are, indeed, afraid of, and which adds more than anything else, animation, interest, and poetry to life.

Liquid Fuel

THE use of oil fuel burnt free in air for steam raising and other industrial heating operations was the subject of a paper by Professor J. S. S. Brame, read before the Institution of Petroleum Technologists.

He pointed out that until within quite recent years the term liquid fuel was understood to refer exclusively to the heavier classes of oil used as fuel under boilers or in furnaces for metallurgical and other general heating purposes. But with the introduction of the internal combustion engine it has acquired a much wider significance, and now covers the whole range of petroleum and shale-oil products, from the light gasoline to the heavy oils formerly used only for combustion, including also such fuels as benzol and alcohol. The air, by the aeroplane, and the sea, by the submarine, have been brought into subjection by men through the agency of the oil engine, and the importance of liquid fuel, burnt for raising steam, is no less important in the Navy. The position, as far as the Navy and the mercantile marine are concerned, is explicitly explained by the highly burnished shovel on "all-oil" ships, displayed in a prominent place and inscribed "Lest we forget."

QUALITIES AVAILABLE

The calorific value of petroleum oil fuels does not vary over very wide limits, and in this respect they show to marked advantage over coal, the calorific value and composition of which vary widely, notably in the amount of true combustible matter present in different samples. In this country particular interest centers round our only native supplies of fuel oils—the shale oils of Scotland, and the tar oils, or even tars, produced throughout the country. The higher boiling oils from the Scotch shales are almost ideal for fuel purposes when the paraffin has been removed, and the coal-tar products are likely to play a far more important part as fuel in the future. In the normal state of things, it is fairly certain that we shall be producing far more tar than is required to furnish all the special by-products for which there is a market, and much will be available for fuel.

In addition to the ordinary tar from the carbonization of coal at high temperature in gasworks, a large supply of liquid fuel may be forthcoming from the low temperature carbonization which is advocated as a means of solving the problem of a smokeless fuel for the ordinary domestic grate. If half the domestic consumption of coal, about 35 million tons annually, were replaced by low-temperature coke, in the carbonization of which probably some 18 gallons of tar per ton would be obtained, over 300 million gallons of tar would be available. From this a large quantity of motor spirit would be distilled off and valuable cresylic acids obtained, but a large proportion would undoubtedly find applications as liquid fuel.

METHODS OF COMBUSTION

The general failure of systems in which the heavy oils were gasified and the resulting gas burned led naturally to attempts to burn the oil in the next best physical condition, that of a fine spray. The elementary principles underlying the design of atomizers are very simple. No particular type or pattern of atomizer possesses superlative superiority; success in burning oil fuel depends but very little on the atomizer, provided the design is good in certain general particulars, but mainly on the general design of the whole oil-burning system. There are three main types of atomizer:—(1) Those in which the oil is broken up by the impact of a jet of steam and air under pressure; (2) those of the injector pattern; and (3) those in which no spraying agent is employed, but oil, raised sufficiently in temperature to lower its viscosity and coherence, is forced under pressure through suitable orifices, in some cases striking against an external baffle. All these methods may be relied upon to give satisfactory results; it is a question of the advantages and disadvantages of each in practice.

Steam has the great advantage that, once the pressure in the boiler has been raised, the atomizing agent is available in unlimited quantities and at any pressure likely to be demanded; but it necessitates that one boiler must be started with other fuel or that a small auxiliary boiler be provided. The consumption of steam is usually about 4½ per cent of the total generated; all this is lost and the extra feed-water thus required becomes a serious question in marine practice, because it entails increase in the evaporating plant. Steam is thus precluded in a vessel with a large boiler installation, but it is frequently employed in mercantile marine vessels where the boilers are of moderate size and few in number. Usually steam atomizers do not respond so well as air or pressure systems when boilers have to be forced.

Air may be termed the natural atomizing agent because it not only effects the spraying, but in doing so should also ensure that every little oil globule is carried forward with the air, requisite for its combustion. This largely accounts for the satisfactory results obtained with many crude forms of air-sprayers—they can hardly be termed atomizers. Many of these atomizers work with pressures that are within the limits of rotary compressors.

Where a number of boilers are installed in a limited space, pressure atomizers are the most suitable. They show their advantages over steam in particular, and so marked are these advantages that the pressure system is almost general in modern installations for maritime purposes. It is indeed without a rival under the special conditions of naval use, where space is at an exceptional premium, where the boiler output is tremendous, and where the oil consumption per boiler has greatly to exceed that common in the mercantile marine. The compactness of the oil-pumping plant and the recovery of all steam used are the important factors in favor of the pressure system.

FURNACE ARRANGEMENTS

Experience shows that ample combustion space is necessary. Given that, with sufficient length from front to back to allow of combustion being practically complete if the air admixture is satisfactory, no special arrangements are required beyond a lining of firebrick in the front part of the furnace. Any deficiency in length, as, for example, with a fire bridge in a short furnace boiler with combustion space beyond, can be rectified by a firebrick-lined extension of the front of the furnace.

In water-tube boilers the requirement of ample combustion space is in general easily met, but great attention is required to the path of the flame and hot gases to attain uniform heating. If proper baffling between the rows of tubes is not introduced, the efficiency and endurance of the boilers are adversely affected. Again, water circulation depends on uniformity of heating. The wide-angle cone from most pressure atomizers is particularly well suited to this type of furnace.—*London Times Engineering Supplement.*

The Self-Made Troubles of a Deer

IN the gentle art of getting into trouble one of our specimens of Hangul deer rivals the giraffe. During the last three years scarcely a month has passed wherein this powerful and savage animal has not made it necessary to call keepers to extricate him from awkward situations of his own creating, or summon the wire-workers to make repairs. Though in a spacious yard with a number of trees, and with every opportunity to take exercise, this animal's favorite pastime is to lunge at the fence in an endeavor to break the vertical wires. We have twice noosed him in order to remove portions of tree boxes which he viciously charged and tightly wedged upon his antlers. Once after a storm, during which telephone wires were blown down, he managed by diligent worrying of a wire to wrap about twenty-five feet of it tightly about his head and antlers. It was necessary to tie him to the fence in order to cut away the tangle. He afterwards repeated the wire exploit by tearing out a mesh partition. Recently, by thrusting his muzzle between two gate posts he managed to run a gate hook through his upper lip. The hook was attached to a chain, but fortunately the latter came loose without tearing the animal's mouth. A squad of keepers drove the maddened deer to a corner of the corral, where a lasso over his horns brought him to the fence. The hook was removed with difficulty, and the injury quickly healed. In adjoining yards, of quite similar construction and condition, our large elk herd, containing several vigorous bucks, has lived for 16 years without any of the troubles that so often have been invented by the Hangul deer.—*New York Zoological Society Bulletin.*

Press Illustrating Service, Inc.

An elaborate chest of Venetian design

Press Illustrating Service, Inc.

Working out a bust of Robert Burns

Carving in Wood

The Oldest Art of the Human Race

A FONDNESS for decoration is one of the earliest instincts of man, and it is by no means limited by race, class or condition, for it manifests itself in the primitive savage as strongly as among the most cultivated people of later times. Indeed, as far back as human records go, even in the cave dweller of prehistoric times, we find the decorative instinct strongly developed, as is shown by the fragmentary implements that have survived.

While decorative effects are wrought upon, and with every kind of material, wood, bone, stone and metals, undoubtedly the first efforts in this direction by primitive man were directed to wood, for it is the easiest of all to work, and consequently the first that would be made use of for the various implements that man would require. In ethnological collections from every part of the world, and representing every age, we find attempts at decoration by carving upon every implement used for domestic purposes, upon bows, arrows, spears, paddles; and these carvings, at first rudimentary in character, and consisting of merely incised lines and dots arranged with more or less regard to symmetry, later developed into more ambitious efforts to produce intricate designs, and to cut figures of various kinds in steadily increasing relief.

The tools of the early carver were naturally bits of sharp stone or shells, and even with these crude implements surprisingly effective work was accomplished, indicating wonderful patience and care, and an unexpected feeling for harmony of design in so rude a people. As civilization advanced and better tools became available, the carving of wood developed rapidly to an art, reaching its culminating point in the twelfth to fifteenth centuries. Since that time wood carving as an art has sadly degenerated, until today it can hardly be regarded as more than a trade carried on with a view of mechanically and perfunctorily breaking up surfaces that otherwise would appear bare and flat, and such as it is, much of it is only the product of a machine.

Unfortunately much of the history of the development of wood carving is lost to us, owing to the perishable nature of the material, but the wonderful specimens of the work of the middle ages are sufficiently numerous and complete to show the wonderful beauty and richness that a skilled artist can add to interior decoration. A reason for the successful results attained by the old carvers of that period was that the carver was also the designer. He put his heart into his work and every stroke that he made was with an endeavor to delineate the conception of his mind. There was individuality and purpose in every line. When the carver began to reproduce the ideas of other men all of this individuality and elaborate care disappeared. He gradually became a mere mechanic and the spirit of the old art decayed. That this should be the case is to be greatly regretted, especially when we view the sums of money now squandered on the stereotyped and machine made decorations not only in our public buildings but in the veritable palaces that our wealthy classes are erecting in such numbers to-day. That there should be a field for the artist carver would be indicated by the extravagant sums paid by some of our multi-millionaires for the beautiful carved work from European churches and ancient buildings to be incorporated in their modern palaces. It may be that the money value of these old carvings is the standard by which they are esteemed; but if it were otherwise it would be almost impossible to obtain modern work of the same character, as modern artists capable of creating acceptable designs would hardly condescend to take up the carvers' tools and create their ideas. This is in curious distinction to the painter, for what real artist in colors would think of turning over his conceptions to a journeyman to reproduce.

Amateur work. Nasturtium carved in one piece

Several of the accompanying illustrations show the modern commercial carver at his work; but that an appreciation of the beautiful decorations that can be created in wood is not altogether dead is indicated by three of the pictures which show specimens of the work of an amateur carver, who works for his own pleasure. These are from the hand of Mr. John K. Blogg, a business man of Melbourne, Australia, who derives much pleasure from the practice of this ancient art. These specimens were carved in what is known in that country as Colonial White Beach, but which is really a sort of white mahogany. This wood the artist describes as exceptionally well adapted for fine carving, as it can be obtained in large sizes, free from knots; it is easy to cut, has fine entangled fiber and all other good qualities that make it an ideal wood for the production of fine work.

Tungsten Ores in Malaya

THE total export of tungsten ores from the Federated Malay States for the year 1915, was 291 (long) tons, made up of 234 tons of wolfram and 57 tons of scheelite, says the London Chamber of Commerce *Journal*. The corresponding figures for 1914 were: wolfram, 233 tons; scheelite 29 tons. Tungsten ores aggregating about 405 tons were imported from other countries and re-exported after treatment, and are not included in the above quoted figures. It is remarked by Mr. W. E. Kenny, Senior Warden of Mines, in his annual report on this subject, that it is not generally realized that tungsten ores do not commonly occur in the Malay States in defined deposits, and that by far the greater bulk is found in small quantities irregularly intermixed with tin ore and valueless matter. These facts make it impossible to obtain any large increase in output. Every effort has been made to stimulate production. Export duty has been suspended, and special terms have been given to prospectors and also as regards mining rights, though the high price that ruled would, under different natural conditions, have been sufficient to augment production.

Motor Agricultural Work in France

M. LOUIS FOREST gives an excellent resumé of the motor agricultural problem in France. The question is one of the greatest interest for that country at the present time on account of want of labor both now and after the war, and there is a movement on foot to promote the use of all such machines. But there are many drawbacks to overcome, and machines must be adapted to local conditions there. Farm property is greatly divided up, and there are only 138,000 farms of over 120 acres in a total of 5,688,000. This condition is a drawback for motor machines, for these in principle require large spaces and are not well adapted for working small fields. Proper association, or working in common, is recommended. All these obstacles can be overcome, if the right spirit is shown. Routine is giving way in many places, and in certain regions peasant cultivators hitherto refractory are now taking up motor working. Again, mutilated or refused men are becoming motor drivers. Indications point to a widespread movement. The French government is considering the best way to promote the question. In short, there appears to be a great future in store for the use of all kinds of motor labor-saving machines.

Press Illustrating Service, Inc.

Boy and girl modeled in rough wood

Press Illustrating Service, Inc.

A plaque with Shakespeare's face

The Use of Supplementary Lenses

A CORRESPONDENT recently suggested that it would be useful to have a table showing at a glance the effect of adding supplementary spectacle lenses on to ordinary photographic objectives. No doubt such a table would be of use, but, unfortunately, it is not possible to make a very comprehensive one, since the possessor of a photographic lens seldom has the particulars necessary to enable him to make full use of the table. To get exact results we want to know the focal length of our lens and the amount of the optical separation, and the former is seldom known exactly, while the latter varies very materially with lenses of different types, and is a factor that cannot well be ignored. If we add a supplementary negative lens of about 16 inches focal length to a doublet of about 8 inches focal length, neglect of the separation gives an answer that is 2 inches too much—about 16 inches instead of about 14 inches, and this is a material error. It is therefore impossible for any table to be absolutely right. Our correspondent submitted a rough table showing the effect of using a very varied series of supplementary lenses, from 1 inch up to 40 inches, which table not only ignored separations, but apparently assumed that very short focus supplementaries could be used with impunity, and also that spectacle lenses of focal lengths in inches could be obtained readily. We fear, however, that no photographic lens would preserve much of its defining power if compelled to work in conjunction with a 1-inch spectacle lens, while there would be great difficulty in getting such a lens at all.

For economic reasons it is inadvisable to ask for lenses that are not of stock focal lengths, and spectacle lenses are stocked in powers measured in diopters, not in focal lengths. Thus the request for a 40-inch lens may lead to the supply of one of 39.4 inches, which is the nearest regular power, or, if the order is taken too literally, to the special manufacture of a 40-inch lens which may cost a good deal more. A lens of a power of 1 diopter has a focal length of 1 meter, or 39.37 inches, and the power varies inversely with the focal length, so that a lens of 2 diopters has a focal length of half a meter. Lenses are usually stocked in powers varying by one-quarter of a diopter, and the following table gives a series from ½ to 3½ diopters, which covers all that are at all likely to be required for use as supplementary lenses. The focal lengths in inches are approximate only.

.5 D=78¾	2. D=19⅝
.75 D=52½	2.25 D=17½
1. D=39.4	2.5 D=15¾
1.25 D=31½	2.75 D=14⅜
1.5 D=26¼	3. D=13⅛
1.75 D=22½	3.5 D=11¼

The table applies to either positive or negative lenses, a plus sign being prefixed for the former and a minus sign for the latter when ordering. Positive lenses are required to shorten the focal length and negative ones to lengthen it. Double convex or double concave lenses are most easily obtained, plano or meniscus lenses generally having to be specially ordered. The form does not matter very much so long as only low-power lenses are used, and only low powers are suitable for use as supplementary lenses.

To find the supplementary lens required to alter focal length, first find the separation, or its nearest equivalent, which may be taken as about half the length of the doublet, if that is of the symmetrical type. Deduct this dimension from the focal length of the doublet, and multiply the result by the focal length required. Then divide the result by the amount by which the focal length is to be shortened or increased. For example, suppose we want to reduce an 8-inch lens to a 6-inch one—that is, reduce the focal length by 2 inches. We may take half the length of the doublet as being 1 inch, and deducting this from 8 and multiplying by 6 we get 42. Dividing this by 2, we find that a lens of 21 inches is required. This must be a positive lens. The nearest to this is a lens of +2D power, or 19⅝ inches. To increase the focal length from 8 to 10 inches, or by 2 inches, we should proceed similarly. Multiply 8–1 by 10 and divide by 2, the result being 35, which is nearest to 31½ on our table, that is to a lens of –1.25D.

Roses, carved by an amateur

Geranium, one piece carving, by an amateur

It will be noticed that in neither of these cases is a lens of the exact power required available. In the second case we have to use a 31½-inch lens instead of one of 35 inches. To find out what effect this variation makes we can calculate the focal length of the combination of doublet and supplementary lens as follows:

Multiply the two focal lengths together and divide the result by the sum of the two focal lengths minus the separation; remembering that if the supplementary lens is a negative one its focal length is a negative quantity. Thus in the first of the examples given above we multiply 8 by 19⅝ and divide by 8+19⅝–1, the result being 5.9 instead of 6 inches, which was the result aimed at. In the second example we multiply 8 by –31½ and divide by 8–31½–1 the result being 10.3 instead of 10 inches. Trial will show that a lens of –1D would have given 9¾ inches as the result, so that we have the choice of two, both giving nearly the length required. Speaking generally we may say that lenses of lower power than 1D are not necessary, while those below 2½D are not advisable. Variations of less than ½D are not required as they make little difference. Powers of 1, 1½, 2, and 2½ D are most useful, and their effect on lenses of 3, 4, 5, 6, 7 and 8-inch focal length can be very approximately gathered from the following table, in which we have allowed for separations varying from ½ inch to 1 inch according to the focal length of the original lens.

Supplementary Lenses, Powers in Diopters.	Original Focal Lengths in Inches.					
	3	4	5	6	7	8
+2½	2⅝	3¼	3½	4⅛	5	5⅛
+2	—	3⅜	4⅛	4½	5⅛	6
+1½	—	3⅝	4⅜	5	5¾	6⅛
+1	2⅞	3⅞	4⅝	5¼	6	7
–1	3⅜	4½	5⅛	7	8⅛	9¾
–1½	—	4⅝	6	7⅛	9	11
–2	—	4¾	6⅛	8¼	10	12½
–2½	3⅝	5⅛	6¾	9	11⅛	14⅛

Blanks are left in the 3-inch lens column because the different effects of 1½ and 2D supplementary lenses are negligible. The former may be considered to have the same effect as 1D and the latter the same as that of 2½D. The most useful variations are given with lenses of 5-inch focal length and upwards.

As before said, 2½D is the strongest lens of the simple spectacle type that we can recommend. If greater power is required it is best to get a corrected supplementary lens specially suited to the original objective, and the makers of this original are best capable of advising in regard to the particular type of lens suitable. In the case of anastigmats it is always advisable to consult the makers, as some forms of such objectives can very readily be upset as regards their corrections.
—*British Journal of Photography.*

Engineering Precautions in Radio Installations*

Various Possible Dangers and Means for Avoiding Them

By Robert H. Marriott. Expert Radio Aid, Navy Yard, Bremerton, Washington

Probably all devices used to produce some desirable result may, under certain conditions, produce or contribute to the production of undesirable results, or damage. The probability of damage from radio apparatus compares favorably with that from other useful devices, and is apparently decreasing. However, radio apparatus may produce damage, and a discussion of the matter may result in future prevention of damage.

In this paper the subject will be considered under four general headings:

1. Wherein dangerous shocks may be received from radio apparatus.
2. Wherein radio apparatus provides a path for currents other than radio currents.
   (a) Lightning.
   (b) Antennas coming into contact with lighting or power lines.
3. Wherein radio apparatus provides the current or potential by direct discharge.
4. Wherein radio apparatus provides the current or potential by induction.

1. Injurious shocks may be received from the transmitter circuits used in very high power stations or in lower power stations should the operator come in contact with the power transformer secondary when the transformer is disconnected from the radio circuits. Radio frequency currents are usually, at worst, only disagreeable.

There are, or were, a few cases of dangerous practice along these lines. One was to shunt the operating key, so that the transformer secondary was at a fairly high potential when the key was open. Another dangerous method and probably by far the most dangerous to the life of the operator, was to use alternating current primary generators which gave an open circuit voltage as high as 500 or 600 volts and connecting that high voltage circuit through the operating key.

Possibly it is reasonably safe to use a generator open circuit voltage as high as 250 but, all things considered, it may be best to bring this voltage down nearer 110, even if efficiency of transformation has to be sacrificed slightly.

2 (a). The danger of fire being produced by lightning striking the antenna is apparently less than the danger in ways mentioned under headings 2 (b), 3 and 4. Personally, I have never seen lightning strike an antenna, nor have I seen evidence that lightning had struck an antenna. However, I have frequently seen antennas discharge to ground when lightning apparently struck at some distant point. For example, in one case, using an antenna 200 feet (60 meters) high, the discharge jumped a gap of 3.5 inches (8.7 cm.) to the ground. On several occasions, in mountainous districts, I have seen lightning striking apparently on all sides of a radio station. On one such occasion, lightning struck a one-story house about six blocks from an antenna 200 feet (60 meters) high. On another such occasion, lightning apparently struck a high tension line near the radio station, judging from the crash which was apparently coincident with the flash and from the fact that the high tension transformer in the sub-station within a couple of hundred feet was burned out.

2 (b). At one time a report was brought in that lightning had struck a radio station burning up the receiving apparatus. On investigation it was found that someone had changed the antenna wires from their former position and had placed them across and above a 1,200 volt line. When the rope supporting the antenna stretched, the antenna dropped down on the 1,200 volt line and grounded this line through the receiving apparatus, burning up the receiving apparatus. On other occasions, antenna wires have dropped across telephone lines, and lighting and power circuits. In the case of the telephone lines, the radio transmitters discharged to telephone line, usually short-circuiting the telephone lightning arresters; while in the case of the lighting and power circuits, the power circuits usually were short circuited, burning out fuses. However, in those cases, had the receiving instrument been connected, it is possible that the power circuits might have discharged through the receiving instruments and burned them.

In cities where lighting, power and telephone circuits are exposed, trouble may arise from antennas dropping across such wires, and in the larger cities where fire alarm circuits and telephone circuits frequently run across the roofs of houses, these circuits may be frequently damaged by antenna wires dropping across them and by their receiving direct discharges from the transmitters.

The greatest number of fires I have noticed starting from direct discharge of transmitters have been where roof insulators or deck insulators leaked current to the roof or deck, and where the roof or deck was of some combustible material. However, none of these fires have resulted in serious conflagrations, probably because they almost invariably occurred during rain or very damp weather, the dampness or rain serving both to short-circuit the insulator and put out the fire.

Portions of transmitters, such as condenser supports, transformer supports, etc., have frequently been charred to some extent. There is less danger of fire being caused by the apparatus which is mainly in use now because, with the exception of auxiliary apparatus as used by one company but now being discontinued, the plain antenna method of connection of the transmitter has been discontinued. This plain antenna connection brings the full spark gap potential to the roof or deck insulator, thereby causing it to break down. A majority of the cases observed where the roof or deck was set on fire were brought about by this type of apparatus.

For the benefit of persons who have not given thought to the subject of insulating radio transmitters, a few points concerning insulation may be proper. These points refer mainly to the transmitter and include the antenna.

A. Air is a good insulator. Its insulating qualities are least liable to be affected by dust, moisture, or age; also, it is cheap. That is, it is desirable to use plenty of air space, when practicable, between points where a discharge might take place.

B. Long and narrow surface insulation is desirable, much on the same principle that a long, narrow conductor has a higher resistance than a short, thick one.

C. Insulators having corrugated surfaces, or surfaces which furnish tortuous paths, are desirable, as such insulators require radio frequency currents to travel over long paths. For the same reasons, such insulators are desirable for direct current and audio frequency potentials.

D. Non-combustible, non-absorbent materials (for example, porcelain) are preferable for insulators where it is possible to use them.

E. Insulator surfaces should be kept clean and dry.

In the earlier days of radio work, a common method of bringing the antenna through the wall of the house was to bring this connection through the middle of a large window pane. This practice was usually fairly satisfactory and not very expensive.

For inside work, the writer adopted a general rule of providing surface insulation equal to eight times the sparking distance through air. For example, if the wire used in the circuit would spark to objects at a distance of one inch (2.5 cm.) through air, this wire was held away by a porcelain rod one inch (2.5 cm.) in diameter and eight inches (20. cm.) long.

Porcelain cleats in series are probably as inexpensive an insulator as may be used for guying small antennas, considering their insulating qualities.

4. For the purpose of this paper, the currents which are set up in conductors not connected to antenna, but due to the radio frequency currents in that antenna, will be referred to as "induced radio currents," and the transference of energy from the antenna to other unconnected circuits will be referred to as "by radio induction."

The greatest damages from fire whichis known to me have occurred where the transmitters were not connected with the point which took fire. In these cases the transmitter caused high potentials in conductors which were more or less distant from the transmitter; that is, these conductors acted somewhat as receiving antennas, and were close enough to rise to a high potential. Where these conductors consisted of telephone circuits the lightning arresters provided on the telephone circuits usually short circuited to ground by the fusing of the metal in the arrester.

This grounding of the telephone circuits usually rendered the telephone circuit inoperative. In the cases of lighting and power circuits carrying direct current or alternating current, such as 60 cycle alternating current, the high potential radio frequency alternating current induced on these lines was apparently superimposed on the direct current or audio frequency alternating current. The radio frequency current produced on these lines was frequently of very high voltage comparatively while the other current (direct, or audio frequency) on the lines was of comparatively high amperage. When the radio potential occurred at a point within striking distance of an object at opposite potential, it apparently discharged and carried the direct current or audio frequency current over after it. In many cases the arcs so formed held until the terminals of the arc or part of the circuit burned away. Power transformers, lighting transformers, motors, generators, relays, magnetos, watt meters, ammeters, volt meters, lamp sockets, rosettes, etc., burned out or were rendered inoperative apparently from this cause. On a number of occasions lamp cord carrying 110 volt direct current, or 60 cycle alternating current, has been short circuited, and on one occasion an 8-foot (2.4 meters) drop cord disappeared in flame and a nearby motor was short circuited. On other occasions, lamp cord lying against wooden moulding short circuited and burned, setting fire to the wooden moulding. On these occasions, people were nearby and put the fire out before it reached any material magnitude.

On one occasion receiving and transmitting apparatus were located very near to the transmitter. The result was that motor and generator windings, relay windings, reactance coil windings, etc., were repeatedly short circuited. This was stopped by providing radio frequency paths through condensers across points which developed high radio frequency potential; also, by placing the wiring in grounded iron conduit, and the short sections of wiring of the switchboard in grounded lead covered wires; and finally, by placing a grounded wire netting screen between the transmitter and the apparatus. All of these expedients were put into effect before noticeable potentials were avoided.

Radio frequency currents possibly in some cases have been superimposed on high tension circuits of the transformers, at least across portions of the secondary of such transformers. It is not quite so easy to conceive how this radio frequency potential may occur in the secondary where so many turns of fine wire are used.[1] However, when transformers were placed in certain relation and near radio frequency circuits they broke down sometimes between sections and sometimes from secondary to primary, and similar transformers when substituted and moved further away or turned at an angle did not break down.

In the United States in 1901, in order to prevent induction in mast guys, these guys were made of rope. In 1902, owing to the stretching and contraction of the rope in dry and wet weather, the writer substituted steel guys with rope blocks and falls at the bottom of the guys to serve both as insulators and as means for adjusting the guys. About this time, or before, others used wooden strain insulators in the guys. On some occasions both the rope insulators and the wooden strain insulators were burned by current leakage between the guys and ground. Even on shipboard, attempts were made at times to insulate guys and stays between masts. However, owing to the difficulty of providing insulation which would not leak, the principle of thoroughly grounding stays and guys was adopted. Stays and guys and other metallic conductors, such as hand rails, occasionally discharged to passengers, causing considerable excitement and fear on the part of some steamship companies that passengers might be electrocuted. The remedy used for this was thoroughly to ground stays and guys, etc. Even the metal whistle cords on vessels occasionally discharged to damp wood work, etc., and often a person who tried to manipulate the whistle received a shock. These were grounded by using flexible wire ground connection. Steel beams, steam pipes, long bolts, anchor chains, and other conducting materials on vessels, have been known to spark to ground or to other conductors. Conduits containing electrical wiring have apparently discharged to the ends of wiring where the conduits were not grounded. Metal roofs in the vicinity of land stations, and metal roofs of wharves, have discharged to ground, causing charring of the wood to such an extent that fear of fire resulted.

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[1]A probable explanation is the distributed capacity of the secondary windings and consequent internal resonance effects with breakdown.

On account of sparking on their vessels, one line had a tendency to accuse the radio apparatus of being responsible for nearly anything that went wrong with the electrical circuits on the vessel, even going so far as to say that the radio currents went down through the vessel and into the water condenser of the engine and caused electrolysis to such an extent that the water condenser had to be replaced!

On a line where the vessels were almost entirely constructed of wood, sparking, charring, and injured apparatus resulted at a number of points. The mast stays were wrapped with houslin and passed through thimbles connected to the hull of the vessel, thereby insulating the mast stay from the hull of the vessel by the houslin. This houslin was set on fire and burned away, due to the sparking between the mast stays and the hull of the vessel via the thimble. On these vessels the mast head lights, running lights, and port and starboard lights, were connected to the pilot house signal light switch board by means of rubber covered twin conductors without metal covering. All of these signal light circuits were burned out from time to time due to sparking across the lines or between the lines and ground. Annunciator circuits and call bell circuits throughout the vessels discharged to metal portions of the ship, and in some cases caused slight charring of woodwork.

On one occasion a steamship company asked that their vessel be gone over with a view to preventing any possibility of igniting explosives which they expected to carry. In this case it was recommended that all metallic conductors in the hold and in the vicinity of the hold be thoroughly grounded and electrically connected together, even the short metal ladders and supports which extended from one deck to another.

Three instances are recalled of wooden masts set on fire due to the discharging of guys to each other through the woodwork of the mast. In two of the cases the masts were burned off several feet from the top. In these cases the guys were 50 feet (15 meters) or more from the antennas.

It has been found that radio currents were induced in the metallic paint on masts and on some occasions the metal paint was removed and a portion of the mast varnished. Some years ago it was the rule to make all radio masts of wood. Also wooden topmasts have been required on shipboard because of the radio apparatus.

Regarding the ability of sparks to start fire, that obviously depends on the heat developed by the spark and the heat required by the combustible material. Very small sparks are almost universally used for igniting gas or gasoline vapor in gas engines, and it is quite possible that similar gas might be ignited by equally small or smaller sparks on shipboard or at other points near radio stations. Sparks developed by radio transmitters might be capable of igniting oils such as are found, for example, in the paint lockers on vessels. Theoretically, radio might cause distress conditions by setting the ship on fire and then relieve these conditions by bringing aid!

While the paper has been confined practically entirely to personal observations, the conclusion is not to be drawn that the damaging results always occur. The instances mentioned practically cover all the cases noted during a period of about fifteen years' use of radio frequency circuits, including radio frequency apparatus operated under a large variety of relations to adjacent conductors at stations on both coasts of the United States, at numerous points inland, and on the vessels of several nations.

Protection against radio frequency currents of dangerous potential being induced in low potential direct current of audio frequency circuits may be brought about to a considerable extent by taking advantage of the ways in which radio frequency currents differ from direct current and audio frequency currents.

Condensers of small capacity impede radio frequency currents very much less than audio frequency currents; (that is, radio frequency currents usually find an easy path through small condensers, while practically no 60-cycle current or direct current will flow through small condensers.) For practical purposes small condensers may be assumed to be good conductors for radio frequency currents and insulators for direct current and alternating current having frequencies in the neighborhood of thirty to five hundred cycles.

Condensers have been installed in series with fuses to ground. This practice is objectionable because if the fuses burn out, the lines are left unprotected at a time when such protection is most likely to be needed, and unless the fuses are in some way arranged to notify some person, it is quite probable that they will not be known to have burned out until after damage occurs to the low tension circuits.

Mica condensers in which lead foil was used have been found to provide automatic self fusing devices without destroying the serviceability of the condenser; for example, when a sheet of mica punctured making a small hole, the lead foil melted away from around the hole until the arc was extinguished and the condenser then operated as before.

Radio frequency currents do not penetrate very far into the conductor, or flow to any great extent in a conductor when that conductor is screened by a concentric conductor such that the radio frequency may flow in the concentric conductor; thus, for example, very little if any radio frequency current will be induced in a pair of rubber covered copper wires enclosed in an iron conduit, where the iron conduit is grounded at intervals.

Low potential circuits have often been protected from radio frequency potentials by grounding the low potential circuits through high resistance rods made up of carbon and clay; and in some cases by using incandescent lamps between the conductors and ground. The writer has always considered this an objectionable practice, because to some extent it grounds the low potential circuits, which are usually better ungrounded. Also, according to the experience of the writer, these high resistance grounds have apparently offered, as a rule, greater impedance to the radio frequency currents than small condensers offered. Slate switchboards sometimes served as protectors to low frequency circuits because their resistance was sufficiently low to allow them to act much as the high resistance protective rods.

Less trouble has occurred since more metal has been used in the construction of ships, in the form of bulkheads, decks and supports. In addition, the doing away with wiring in wooden moulding and the substitution of metal moulding, conduit, and metal covered cable has prevented radio frequency currents from being produced in the direct current and audio frequency wiring. Lead covered wire has been used sometimes, but has occasionally caused trouble when the lead has been mechanically forced through the insulation and against the copper. It is probably preferable to use lead covered wire in protecting metal conduit with drains in the lower portions of the conduit to take care of sweating, etc.

Besides preventing sparking, another reason for thoroughly grounding the stays and mast guys on vessels was the assumption that less energy is absorbed from the radio waves by thoroughly grounding these stays than that which would probably be consumed in the resistance over leaking insulators.

The increasing knowledge and improving practice of professional radio engineers decreases the probability of damage. However, inexperienced persons install transmitting and receiving stations from time to time, using such various types of apparatus as their circumstances and knowledge provide. Such stations as these are frequently erected in private houses, where sparks may occur on combustible material, and where telephone and lighting wires may not be protected by conduit or grounded metal covered wire, and where the antennas may be above or may parallel nearby telephone, fire alarm, lighting and power wires. It might be useful to offer a set of rules to cover the various possibilities, but that would require very careful study, if these rules were drafted, to prevent imposing hardship on the young experimenter and radio student, who generally is limited as to means.

The radio laws which require low decrement and practically single waves to be radiated from transmitters, made for the purpose of preventing interference, may serve as a protection against radio transmitters causing damage. These laws, with their resulting regulations, aid in eliminating the plain aerial type of transmitter whereby the antenna was raised to excessively high potentials, and because of the lower decrement, nearby circuits, unless their natural period is somewhat near that of the radio frequency, may not be excited to such an extent. High group frequency transmitters and especially transmitters of constant amplitude waves use lower voltage for equal power, which results in lower voltages being induced in nearby conductors. These types of transmitters are coming into general use and the constant amplitude wave transmitters may be the transmitters of the future. Therefore, the probability of damage should continue to decrease.

When the current flows in an antenna, magnetic and electrostatic fields are produced around that antenna; therefore all conducting materials in these fields are conductors in the dielectric of a condenser, and at the same time they are conductors which cut a magnetic field. Considering the antenna as one plate and the earth as the other plate, and the air between all parts of the antenna and the earth as the dielectric, all conductors within this air space will be at a different potential from both the antenna and the earth, while this condenser is being charged. As the antenna may be periodically charged to a high potential, the conductors in the dielectric may be periodically at a high potential with respect to earth, depending on their distance from the earth and from the antenna. If these conductors are at any time raised to a potential sufficiently high to break down the solid or air insulation between them and earth, they will discharge or spark to earth. Now, if these conductors are carrying another current such as direct current with a direct current potential difference to ground, then the direct current will as a rule, it may possibly be said, follow the spark, and establish an arc which may hold until the circuit is opened by some portion burning away whether that portion be a fuse, a wire line, or generator winding. In the same manner both terminal wires of a motor or generator may spark simultaneously to the armature core, and produce a short circuit. This may occur whether or not the motor or generator is grounded because the motor or generator usually occupies a relatively different position in the dielectric from that occupied by the line wires.

Where conductors are within sparking distance of the antenna a discharge may take place, although the conductors may be insulated from ground and from the antenna, and this for the same reason that such conductors discharge to ground. For example, antenna circuits frequently discharge to such small masses of metal as wood screws, although the surrounding wood is a good insulator.

Conductors are usually so placed as to cut the magnetic lines emanating from the antenna or the closed circuit of the transmitter; and a potential difference between the ends or portions of a system of such conductors may result which will break down the insulation. If these ends or portions are, for example, the opposite terminals of a motor or generator, or the terminals of a magnet, a short circuit may result. The electrostatic and magnetic fields may work together to produce such damage.

The shorter waves formerly used may have corresponded more nearly to the natural wave lengths of conductors which were found on shipboard in the lower potential circuits than do the longer waves used at present.

When the conductor which tends to spark to ground or to the frame of a dynamo is connected to ground or to the frame through a condenser, and where that condenser is relatively of much higher capacity than the capacity of a conductor to ground or to the object to which it tends to spark, the effect is probably somewhat similar to bringing the conductor quite near to the ground or the frame, and the nearer the conductor is to ground or to the frame, the lower the potential difference that exists between the conductor and ground or frame.

That is the conductor will be brought to a point of lower potential in the potential gradient between the antenna and ground. Or this protective condenser may be possibly regarded with fair correctness as a very low impedance so far as the radio frequency potential is concerned; and where a relatively low impedance is in circuit, the potential across that impedance must be relatively low. In other words, a relatively low impedance is provided for the radio frequency current around the insulation provided for the direct or audio frequency current.

Considering the antenna and earth together with the intervening air as a condenser, if we wish to protect conductors in this air dielectric against discharges from one plate or the other of this condenser, we must do one of two things: Either thoroughly insulate the conductors to be protected or connect them electrically to the plate to which they have a tendency to discharge. That is, they must be thoroughly insulated or made part of one plate or the other. As the insulation between low voltage circuits and ground is as a rule only sufficient to insulate the normal potential on the low voltage circuits, it is necessary to provide means for connecting these circuits to ground so far as radio frequency currents are concerned, or to enclose them within the ground plate of the condenser rather than in dielectric.

The case is one of conductors subjected to alternating stress in the dielectric of a condenser and at the same time to an alternating magnetic field.

The problem is to prevent these conductors from sparking. The usual solution is to ground thoroughly all conductors which are not there for the purpose of carrying current, and to enclose current carrying conductors in grounded metal coverings (*e. g.* metal conduit). Where this is not practicable, it is desirable to connect the current-carrying conductors to ground and to each other through condensers (*e. g.* lead foil and mica condensers of approximately 0.17 μf. capacity tested at 500 volts, 60 cycle alternating current and enclosed in copper water-tight cases). In building a radio station, it is desirable to place all current-carrying conductors (other than radio) underground so far as practicable (and especially telephone conductors). The first continuous grounded metal deck of a vessel, below the radio transmitter, may be usually considered as the surface of the ground in so far as this protective effect is concerned.

A One-Quarter Horse-Power Single-Phase Induction Motor—I

Complete Details and Instructions for Building

By Charles F. Fraasa Jr.

PART I

The accompanying drawings illustrate the construction of a ¼ horse-power self-starting single phase induction motor designed for operation on 110 volts and 60 cycles. The synchronous or no-load speed is 1,800 r. p. m., but under full load the speed will drop to 1,730 or 1,750 r.p.m.

The motor operates purely on the induction principle. The current is led into a stationary winding on the stator which produces a rotating or pulsating magnetic field about a short-circuited rotor, inducing in it a current which reacts upon the rotor producing rotation. In a motor of this type, having a short-circuited rotor

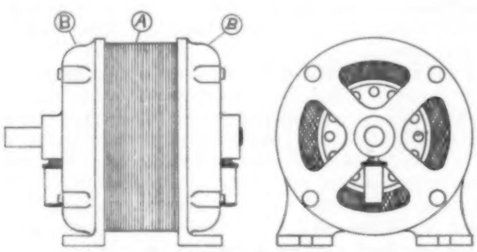


Fig. 1—External view of complete motor

winding, the absence of commutator, brushes, and insulated windings on the rotating element leaves little to get out of order.

An induction motor consists of two essential parts, namely: a primary and secondary winding. The primary is usually wound on the stationary element, known as the stator, and the secondary is wound on the rotating element, known as the rotor. The line current is led into the primary winding, producing a magnetic field. This magnetic field induces a current in the secondary, and the secondary induced current in turn produces a magnetic field which reacts upon the primary field, tending to rotate the secondary or rotor. It is necessary, however, that there be a relative motion of the magnetic field about the stator, in order that a current may be induced in the secondary by the conductors cutting the rotating magnetic field of the primary winding, that there be a relative motion of the magnetic field about or through the stator.

In a two-phase motor, this motion of the field is produced by the difference in the phase of the two currents and by a suitable arrangement of the winding. In a four-pole motor, the four coils of each phase span one-quarter of the circumference of the stator. The coils of the two phases lap over one another for one-eighth of a circumference; that is, the conductors of the coils of one phase are in the middle of the coils of the other phase. When the current is at its maximum in the phase one, it is at its minimum or zero in phase two. At this instant there are produced four magnetic poles of maximum intensity. An instant later the current in phase one is diminishing, while in phase two it gradually assumes value. The result is a diminution of the strength of the four original magnetic poles and the establishment of four resultant poles between the original poles. As the original magnetic poles decrease and the new magnetic poles increase in value, the magnetic field seems gradually to shift from its original position to a new position midway between the original poles. In the succeeding cycles of the current, the poles continue to shift, making complete revolutions around the stator core.

In the single-phase motor, to produce the same effect a different procedure must be adopted. It is necessary in starting to split the single phase into two phases, one lagging behind the other. The same type of winding is used as in the two-phase motor described above, but one phase only is used as a main or running winding, and the other is merely an auxiliary starting winding. This phase winding is composed of smaller wire, having a greater resistance and fewer turns are used than in the main winding. The difference in resistance and inductance between the two windings causes a greater lagging of current in one of the windings, producing a slight imitation of the two-phase rotating field. The phase coil is only used in starting, and when the motor comes up to speed should be cut out of circuit.

The induction motor is virtually a transformer, the stator winding being the primary, and the rotor winding being the secondary. In the transformer to get good power-factor and regulation, the primary and secondary coils are placed as close together as possible, and air-gaps are eliminated. In the induction motor this is also essential, though the coils must be separated to allow for the rotation of the rotor. In a motor of this size, the air-gap should be very small, but sufficient to give a mechanical clearance.

As the rotor winding is short-circuited upon itself, it is not necessary that it should be of the wound type, but may be composed of copper bars short-circuited to

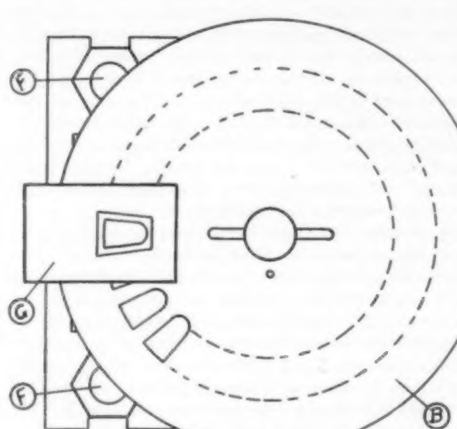


Fig. 2—Indexing device for punching laminæ

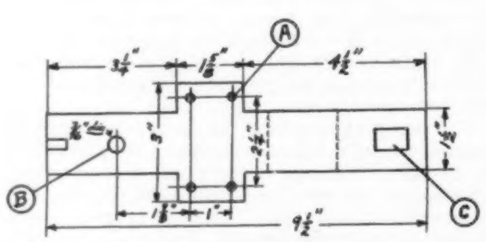


Fig. 4

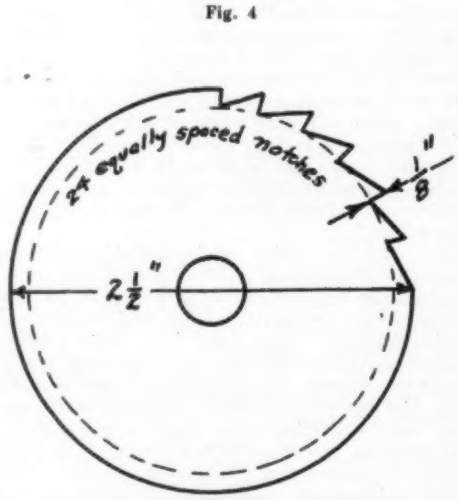


Fig. 5

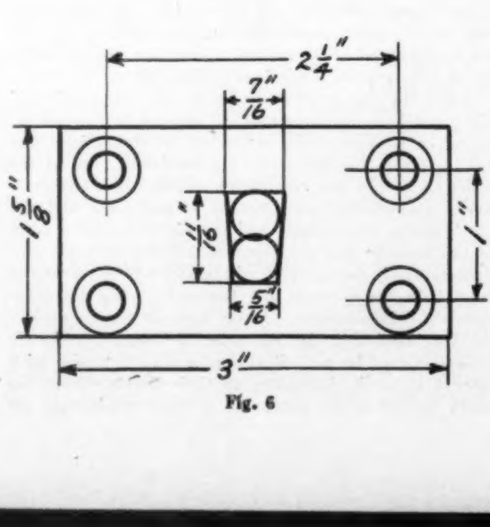


Fig. 6

copper end-rings. A rotor of this type is very rugged and practically indestructible.

Figure 1 illustrates the complete machine. The stator (A) composed of laminations of sheet steel, having slots punched around their inner periphery is mounted between the two cast iron end-plates (B). The rotor is of the bar wound type having copper bars inserted through holes drilled around the core near the periphery. As none of the parts are of standard manufacture, it will be necessary for the builder to prepare his own stator and rotor laminæ. The use of good machine tools will be necessary, but most manual training and night high schools are well equipped, and many amateurs have

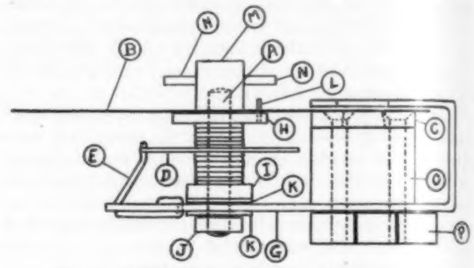


Fig. 3—Indexing device for punching laminæ

their own individual equipment, making it possible for an increasing number of amateurs and students to construct electrical machines.

For making the stator and rotor laminæ, it is not assumed that the reader owns or has access to any special step-by-step disk-notching press, so data are given for punching these on any small hand or power punch press that may be available, or, as in the instance of the writer, by the use of a slotting attachment on a small milling machine. The rotor is of simple construction, the holes for the bars being merely drilled around the periphery.

For punching the slots in the stator disks, the device shown in Figures 2 and 3 should be constructed. This consists of a mandrel (A) on which the disks (B) are supported and rotated when punching the slots, and a die (C). The disk (D) is mounted on the mandrel with the laminæ, and has notches around its periphery, which are engaged by the stop (E) locating the slots. The whole device may be fastened to the frame of a small notching punch (such as are usually found around any machine shop) by means of screws or bolts. It was, however, designed to be bolted down on the table of a small milling machine by means of the two T-head bolts (F). The punch was then placed in a vertical slotting attachment of 2-inch stroke, provided with the machine.

The strip (G), Figures 2 and 3, dimensioned in Fig. 4, is a piece of ⅛-inch sheet iron. The holes (A) and (B) are located with reference to Fig. 2, so that when the die is brought in the proper position the slots will be at the correct diameter. The mandrel (A), Fig. 3, is cut from a piece of ⅜-inch iron or steel rod 2¼ inches long and threaded as shown to receive the nuts and rings as shown in the illustration. The piece (H), ¼-inch thick and 1½ inches in diameter, is cut from a piece of iron and drilled and tapped for the ⅜-inch mandrel, as are also (I) and (J) which are one inch and ¾-inch respectively in diameter. Thin washers (K) are placed under (I) and (J) to enable the mandrel to rotate freely when (I) and (J) are turned up tightly. The disk (D), Fig. 3, detailed in Fig. 5, which locates the slots, is cut from a piece of sheet brass about 1/16-inch thick. The illustration shows how the notches are cut in the disk. With the notches cut in this way, the disk can rotate in one direction only, acting as a stop when turned in the other direction.

The die (C), Fig. 3, dimensioned in Fig. 6, is made of a piece of annealed ¼-inch steel, which any dealer will provide if told for what it is to be used. The slot is formed by drilling two 5/16-inch holes as shown, and then shaping it out with a file to the dimension shown in Fig. 6. To allow the punchings to fall out the slot hole should taper out in all directions on the under side of the die-plate. The four holes in the corners of the die-plates are ¼-inch holes, through which pass screws to hold the die to the frame. Having made the slot hole, the die-plate should be tempered. To harden it, the steel is heated to a bright red, and dipped into oil or luke warm water; but not cold water, for this would make it very brittle. Draw the temper in the flame of a Bunsen burner, wiping the steel frequently with

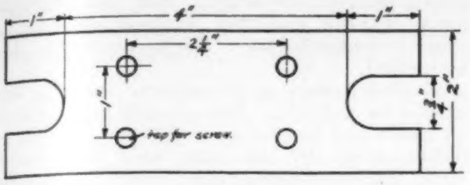


Fig. 7

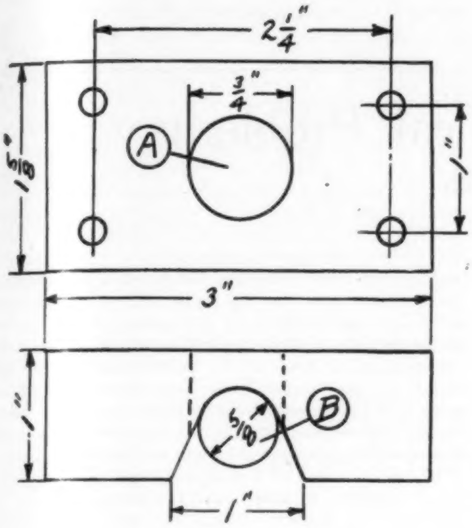


Fig. 8

oily rag during the process. If the reader is not familiar with the handling of tool steel it would be better to have this done by some one having experience.

When the parts are constructed, turn nut (I) on the end of the mandrel (A) Fig. 3, put on washer (K) and then insert the mandrel in the hole in the strip (G). Place a thin washer on the underside of the strip, and then turn on the nut (J). Then put a number of washers and disk (D) on top of the mandrel, and then some more washers, and screw on (H). (L) is a 1/16-inch pin in (H) used as a guide pin. The laminæ will have a hole drilled in them for this pin. When assembling the laminæ the holes are brought together bringing the slots in alinement. The piece (M) is drilled and tapped for the mandrel, and drilled for the 3/16-inch rod (N) by means of which it is turned down upon the laminae. Then put the die (C) and blocks (O) and (P) in place and secure by four screws, which enter tapped holes in the piece (P). Bend the end of strip (G) over the die to form a stripper, leaving a space of 1/16-inch between the stripper and the die. A hole should be cut in the stripper having the same shape as the punch, but slightly larger, so as freely to pass the punch.

The block (O) Fig. 3, dimensioned in Fig. 8, is cut from a piece of iron or steel. The hole (A) is drilled corresponding to the die hole. Hole (B) is cut into the bottom by drilling a ½-inch hole and opening it with a hack saw. These holes should be cut so that the punchings can fall through and out of the die.

In the author's case the indexing device was designed to be bolted to the table of a milling machine by means of T-head bolts in the table slots, and through the strip (P) dimensioned in Fig. 7. The punch was secured in the plunger of a vertical slotting attachment for the milling machine. After the table was adjusted to admit the punch in the die, it was securely locked in position to prevent its moving during the punching. Probably the dimensions will not be satisfactory for the machine to which the reader has access. The device should then be arranged especially for it.

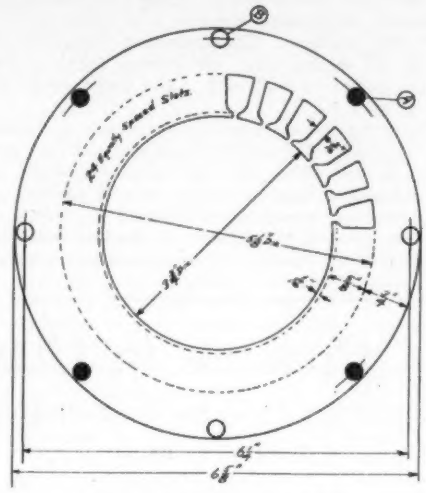


Fig. 10—Details of lamination

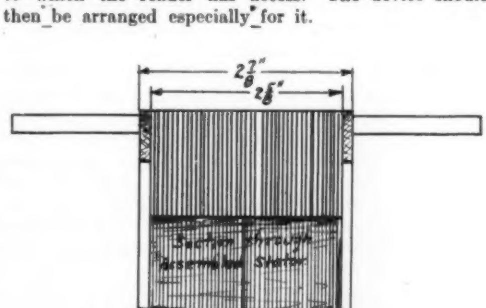
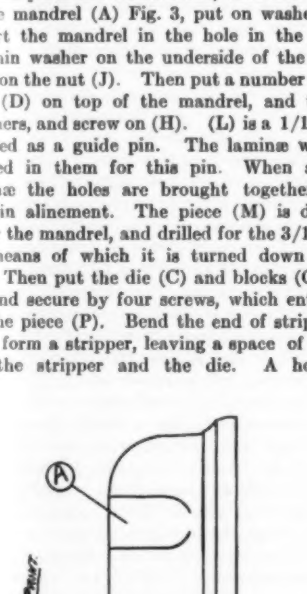


Fig. 11—Assembled stator

The punch is shown in Fig. 9. This is also made of annealed tool-steel, which should be bought in the most convenient shape, and machined to the proper dimensions. The one end is to fit in the punch plunger, or in the writer's instance in a 2-inch stroke slotting attachment capable of holding a tool ½-inch in diameter; then the other end it to make a snug fit in the die-plate slot. The greatest care should be exercised in this work to have all parts and dimensions accurate. The punch is hardened as was the die-plate.



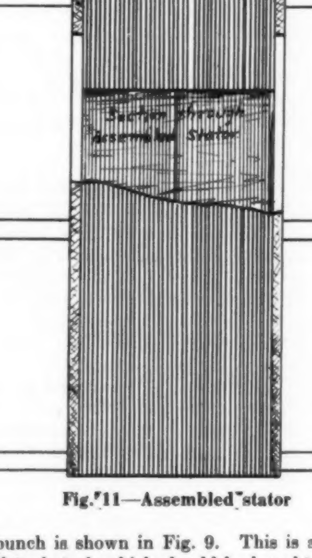


Fig. 13—Details of housing patterns

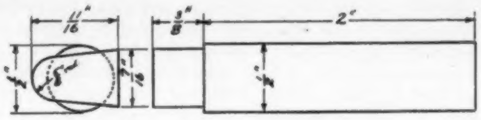


Fig. 9

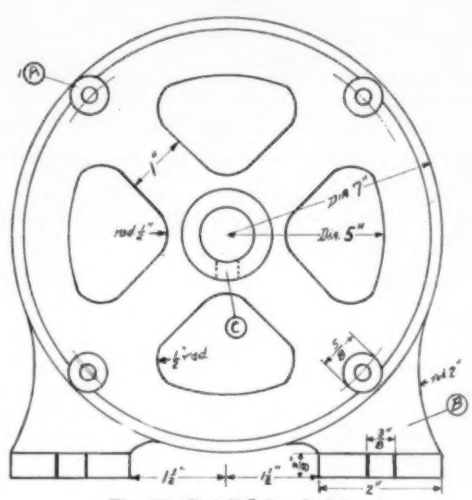


Fig. 12—Details of end plates

PART II

The construction of the stator core, Figures 10 and 11, is as follows: Enough 7¼-inch diameter disks are cut from some No. 27 sheet steel to make a stack 2⅝-inches thick when tightly compressed. These disks should perferably be cut from some electrical steel, or transformer steel, but lacking these, a good grade of stove pipe iron may be used. Clamp the disks down on the drill press with a ⅛-inch thick disk of sheet iron on each side and drill a ⅝-inch hole through the center of the stack. About ⅝-inch from the center of this hole, drill a ¼-inch hole which is to be used as a guide in placing the disks on the punching device, and later when assembling the laminæ. The eight holes (A) and (B) Fig. 10 are drilled with a ¼-inch drill. The four alternate holes (A) in the sheet-iron plates are to be countersunk so that when the rods which hold the laminæ together are rivetted, the ends will be flush with the surface. The disks are then removed from the drill press and mounted one at a time on the mandrel of the punching device. Then turn the disk until the notch on the disk (D) Fig. 3 is engaged by the stop (E) and punch the first slot. Succeeding slots are located by turning the disk ahead one notch and then back until the stop is engaged.

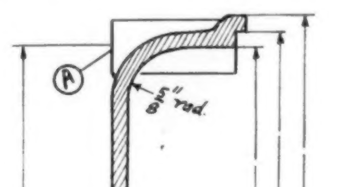


Fig. 14—Section of housing

When the disks are all punched, shellac or japan one side of each disk, and assemble them on the eight ¼-inch rods (A) and (B) Fig. 10, with one of the ⅛-inch pieces of sheet iron used when drilling the holes, on each end. These rods should be about 7 inches long and should be threaded on one end for a distance of 2½ inches and on the other end for about 2 inches. Turn a nut very tightly on each end of the rods to clamp the whole

together. These rods will then project about 2¼ inches on one side of the core. The stator is then fastened to the lathe face-plate by inserting the long ends of the rods in the holes in the face-plate, and turning on nuts to bind it there. When it is centered accurately, cut out the ⅛-inch sheet-iron covering the slots, boring to a diameter of 5⅝-inches. Then set the tool for boring out the stator. To prevent the tool tearing the teeth, the slots should each have a piece of wood of the same shape as the slots forced into them. Then bore to a diameter of 3¾ inhces. The outside of the stator is turned down to a diameter of 6⅝ inches. The nuts on the alternate rods (B) are then removed and the rods sawed off and riveted down. Since the holes for these rods were countersunk, the rods may be rivetted flush with the surface. The remaining four rods shall be cut off so that they will project for a distance of 1¾ inches on each end. The stator should then appear as in Fig. 11.

The end-plates are exactly alike, so only one pattern need be made. The pattern, Figures 12 and 13, is made up of ¼-inch white pine, and turned inside and out. The windows or openings are cut out with a coping saw. Four pieces of ¾-inch dowel (A) each 1½ inches long are then glued in holes drilled at the four equidistant points shown. The feet (B) are cut out and secured in place with glue and brads. Then turn two core prints (C) and glue them in holes drilled in the center of the bearing hub. Two bearing castings will be required.

All sharp corners of the patterns should be well rounded out with fillet. When the patterns are finished sandpaper with No. 0 paper and apply a first coat of shellac. When dry, sandpaper again until smooth, as the first coat of shellac raises the grain and roughens the surface of the wood. Apply a second coat of shellac and repeat until the surface is smooth. At least three coats will be required; on end of wood about four

[TO BE CONTINUED]

The Function of Pressure in Chemical Problems*

An Important Field for Further Research

By Dr. E. Briner

THE chemical phenomena which are manifested in nature, studied in the laboratory by the scientist, or utilized in industry by the technician, depend, in general, on conditions of temperature and of pressure. For a long time the chemist, who was limited to the observation of these phenomena at ordinary temperatures, has endeavored to learn how they were affected throughout the whole range of temperature at his disposal. Each extension of this interval, due to new improvements of technique, has brought forth a rich harvest of discoveries.

These researches have been so fecund of results that they have long led to the neglect of the study of the other factor, pressure. Yet there is equal reason for inquiring what influence is exerted by variations of pressure on all chemical phenomena which have been habitually observed at the ordinary pressure; in particular would not very great elevations of pressure probably cause the appearance of new phenomena?

It must be admitted that from the experimental point of view these efforts are incontestably more difficult than those relating to the action of temperature, and the chemist has often been obliged to hesitate to engage in this new domain because of the complicated and costly apparatus necessitated by such researches.

Thanks to the progress of experimental technique this field of investigation has become more accessible; and in fact of late years endeavors to bring pressure into play have been increasingly numerous. The object of this address is to pass in review certain recent achievements in this direction, and you will pardon me if in this connection I take the liberty of dwelling a little more upon the modest theoretic and experimental contributions which I have been able to bring to the study of this question both personally and by the aid of certain collaborators. You will kindly permit me also to take occasion to express my sincere gratitude to Prof. Ph. A. Guye, in whose laboratory our researches have been pursued, and who has strongly encouraged them, as also to the Auxiliary Society of Arts and Science of Geneva, which has generously put at our disposal the necessary funds for the acquisition of a compressor for securing elevated pressures.

Without intending to enter into details concerning the technique of operations under pressure it seems desirable to set forth some general information upon this subject. Let us note in the first place that the improvements realized have led to the obtaining of higher and higher pressures, and above all to the power of maintaining these pressures for a sufficiently long time. This last point is of capital importance, for often the action of pressure must be exercised for a certain length of time in order to manifest itself or to be capable of measurement. These conditions have been realized, thanks to a perfect tightness of the apparatuses obtained by the employment of hermetic joints—notably the conical joint, or again by the aid of devices automatically re-establishing the pressure at its original value if the phenomenon studied is accompanied by a contraction. The exceptional resistance of the steels which it is now possible to prepare, also enters largely into the success of these endeavors.

A more precise idea of the progress attained in the laboratory technique of high pressures can be gained from the researches of the American *savant* Bridgman, which we particularly note here, though their character is rather physical than chemical.

In operating up to pressures approximating 20,000 atmospheres, this experimenter obtained a whole series of most interesting results, among others the following: When submitted to pressures above 6,000 atmospheres, carbon dioxide presents points of solidification situated above its critical temperature of 31° C., or the temperature above which it can no longer exist in the liquid state. Thus, therefore, at very high temperatures, and if the pressure is sufficiently great, the solid state would be capable of existing side by side with the gaseous state, but to the exclusion of the liquid state; a fact which is of capital importance for cosmogonic theories. At high pressures, solid water, or ice, may present itself under five different allotropic forms; two new varieties of phosphorus have been characterized, a white variety prepared by submitting phosphorus at 60° C. to a compression of 11,000 atmospheres, and a black variety obtained by the combined action of a temperature of 200° C. and a pressure of 12,000 atmospheres. Under this last form the phosphorus possesses properties completely different from those we recognize in it, it is much denser, does not take fire of itself, and is a good conductor of both electricity and heat.

It is to be remarked, however, that such high compressions can scarcely be put in operation except for the study of liquid or solid condensed systems. The compression and the maintenance in a state of high compression of systems comprising a gaseous phase would involve serious difficulties. Without speaking of the risk of escapes it would still be necessary to take into account the tremendous reduction of volume undergone by these systems, a reduction due to the great compressibility of gases.

We may mention here a process for the compression and maintenance under pressure of gaseous systems for as great a length of time as may be desired without danger of escape. This has been of great service in our own researches and is within the reach of all experimenters, having liquid air or other energetic refrigerants at their disposal. It consists in condensing the gases constituting a system in a thick walled glass tube immersed in the refrigerant. When the quantity condensed is sufficient the tube is carefully closed with the blow-pipe and allowed to return to the ordinary temperature; if this is superior to the critical point of the mixture the pressure in the tube will be increased in a degree corresponding to the completeness of the filling. We thus obtain compressions of many hundred atmospheres and we can even follow at our ease the progress of the chemical phenomena induced by observing the length of the liquid, if there is the formation of a condensed phase. Such is the case, for example, if in the compression of the mixture HCl—NO which yields a red liquid NOCl.

The same artifice permits us to submit also to high pressures gaseous systems which, at the ordinary temperatures are constituted by liquefied gases or by liquids; for this it is sufficient to bring the tube to a point above the critical points of the system which it contains. It is of importance, naturally, in these experiments, to take all necessary precautions, since the tubes frequently explode.

Let us add another word as to the processes utilized for the measure of pressures. The manometers for compressed gases usually registers 400-500 atmospheres; above that it is necessary to have recourse to manometers with pistons, or the Bourdon type, For pressures above 500 atmospheres we appeal to the variations undergone by certain physical properties, such as electric resistance when the pressure is increased.

These few brief remarks indicate the importance of correct apparatus in researches effected under pressure. In our opinion that which will conduce to giving a new impulse to such researches, in spite of the difficulties that attend them, is the number of industrial applications of which they are susceptible. In this domain technical obstacles are far more serious than in the laboratory, and practical results can hardly be obtained except by close collaboration between chemists, physicists, and engineering specialists. In return the investigators of the laboratory will certainly benefit by the experience acquired in these endeavors. To cite but a single example of these applications, in which numerous technical difficulties had to be surmounted, and one which is of high present value now, we may mention the process of Haber and Rossignol for the fixing of nitrogen in the state of ammonia, In this process the mixture of nitrogen and hydrogen circulates at a pressure of about 200 atmospheres and a temperature of about 550° C. over catalytic substances, and the ammonia formed is extracted in liquefied form. We shall have further occasion to refer to this reaction.

I

THEORETIC CONSIDERATIONS

In examining the chemical phenomena induced by variations of pressure we are obliged to distinguish very precisely between the action of pressure upon systems in equilibrium and that exerted upon systems which have been removed from their state of maximum stability.

Our atmosphere, for example, composed everywhere of oxygen and nitrogen, is the type of a system in equilibrium. It will undergo no modification as long as ordinary conditions are maintained. On the contrary, the combination of oxygen and nitrogen called nitric oxide is, at ordinary temperature, a system removed from its true state of equilibrium, and as we see, this system is the seat of a slow transformation, which can be very greatly accelerated by compression. Other systems tend to assume their state of equilibrium by very rapid reactions, such as explosives. Considered as a factor of equilibrium, the rôle of pressure has been clearly defined, and it may be predicted qualitatively by the following well-known rule:

"The compression of a system favors the reaction which is accompanied by a diminution of volume." Quantitatively the evaluation of this action will be based upon the application of the principles of thermodynamics, which will lead to the relations sought.

When systems removed from their state of equilibrium are concerned, the rôle of pressure will be less easy to predict, for here we can not apply the principles of thermodynamics. The law of the action of masses probably causes an increase in the speed of the reaction, due to the increased concentration of the constituents by the compression, but it is incapable of giving us complete information upon the states through which the compressed systems will pass, upon the degree of the pressures that must intervene, in a word, upon the special characteristics of the evolution of the system.

To fix our ideas, let us return to the case cited above, of nitric oxide, that of all the compounds of oxygen and nitrogen which is farthest removed from the most stable degree of equilibrium. It was to be foreseen that compression would favor the establishment of this equilibrium; but up to what point will it resist the action of the pressure? What course will it pursue to attain the state of maximum stability? Only experiment can tell us.

It should be remarked here that compression can not be replaced by elevation of temperature, although both these actions tend to accelerate chemical reactions. By the elevation of temperature alone, the final state of equilibrium and the intermediate state will be, in fact, different from those accompanied by compressions at a low temperature. To take the same example, let us raise the temperature to about 700° C., NO will be entirely decomposed into its elements, and after a return to the ordinary temperature we shall have a mixture of N^2+O^2. If, on the contrary, we raise the pressure at the ordinary temperature, as was done by us, we shall

*Address given before the Helvetian Society of Natural Sciences, Aug. 7, 1916, at Schuls.

engender a system constituted by a mixture of nitrogen with various oxides of nitrogen; we shall obtain therefore a system which is greatly condensed and far more complex.

From the view point of the efficacy of action of pressure a general observation is quite naturally deduced from the considerations just developed.

The variations of volume, *i. e.*, of concentration, of the constituents of a system, being factors of the equilibrium of the reaction as well as of its speed, it was to be foreseen that the compression would exhibit itself most actively in systems comprising gases; the latter are, of course, very much more compressible than either liquids or solids. Moreover, the conception of the nearer approach to each other of the reacting molecule, caused by the compression, readily permits us to take account of this consequence. It is chiefly for this reason that we have occupied ourselves with the study of systems comprising at least one gaseous phase. Let us hasten to add, however, that the interest which attaches to condensed systems is no less great. The reactions which take place in the terrestrial crust and core, knowledge of which is so important from the geologic and petrogenetic point of view, are not all these effected under pressure? Researches in this domain unfortunately present the inconveniences of exacting enormous compressions, a thing far more difficult to accomplish in the laboratory.

The preceding considerations thus lead us to classify separately and consider under two heads studies bearing on variations of equilibrium and those in which the experimenters have had more particularly in view variations in the speed of reactions.

II

ACTION OF PRESSURE UPON EQUILIBRIUM

Among the phenomena in this category we may cite the reversible formation of solid or liquid combinations from gaseous products; the latter are not created and can not be studied unless the pressure is superior to their tensions of dissociation.

For example, the chloride of phosphonium, discovered by Ogier, with which we have had occasion to make some experiments. This is a white solid, which, at temperatures of 0° C. and 11° C., is not stable except under pressures of 8 and 15 atmospheres respectively; at lower pressures it is dissociated into hydrochloric acid and phosphoreted hydrogen. Such also is a compound of sulphurous anhydride and methyl oxide, which we have obtained by the compression of these two gases.

We can liken these reactions to the production of the peroxide of calcium CaO_2, which, according to Bergius, does not succeed starting with the oxide and with oxygen, except by sufficient elevation of pressures and of temperatures; the tension of dissociation of these bodies attains, in fact, a pressure of a 100 atmospheres at 200° C.

In another domain, the compression of the nitric oxide NO upon nitric acid has enabled us to elucidate the very complex conditions which exist at the formation of nitrous and nitric acids starting from water and various oxides of nitrogen. Such a compression causes the equilibrium of the system to retrograde in the direction of the formation of nitrous acid; the latter in its turn yields the nitrous anhydride N^2O^3, which gives its blue coloration to the solution, and finally, if in certain cases we raise the pressure to 10 atmospheres, there separates a second liquid phase of a very dark blue color, constituted by the anhydride N^2O^3, which is thus able to exist in a state of equilibrium in the presence of an aqueous phase.

Thanks to pressure, we have thus been able to maintain, in the presence of an aqueous phase, substances in which, at first thought, we could not expect to find this property, since they react very strongly with water, and at ordinary pressure are not stable in the presence of water. We have just cited an example of this nitrous anhydride; we have likewise proved it with other systems, such as $NOCl—H_2O$, $SO_2Cl_2—H_2O$, etc.

This same governing idea, consisting in the study of systems in closed receptacles, *i. e.*, under pressure, has enabled us to explain the mechanism of the reactions produced in aqua regia a reaction which has remained obscure although aqua regia is a reagent which has been known and used since the eighth century. In placing together nitric acid and hydrochloric acid, the mixture of which constitutes aqua regia, in a glass apparatus provided with a manometer and an agitator, we find that there is formed a system comprising two liquid phases surmounted by a gaseous phase, the whole in a state of equilibrium under a pressure which depends solely upon the temperature; at 20° C., this pressure is about 5 atmospheres.

In concluding this chapter, let us say a few words upon the capital rôle played by pressure in another reaction touching on the vital problem of the fixation of nitrogen from the air. We refer to the preparation of ammonia starting from these elements by the process of Haber and Rossignol. As foreseen in theory compression acts in a particularly efficacious manner upon this reaction, and in the direction of the formation of ammonia; this is, in fact, accompanied by a very great reduction of volume. Very convincing are the following figures, borrowed from a memoir by Haber, where *c* is the proportional percentage of ammonia in equilibrium with the nitrogen-hydrogen mixture at various pressures *p* (in atmospheres) and at 600° C:

p	1.	30.	100.	200.
c	0.049	1.43	4.47	8.25

These figures make it evident that without the intervention of compression this synthesis would not have presented the great industrial interest which at present it enjoys. In the process, as it is applied, the compression also acts, naturally, on the speed of the reaction, but this is above all strongly accelerated by the presence of catalytic substances (osmium, uranium, uranium carbide, etc.) whose action, on the contrary, is null upon the equilibrium.

This ammonia can be transformed afterward, industrially also, into nitric acid. We thus obtain, starting with atmospheric nitrogen, which is at our disposal in unlimited quantities, ammonical and nitrated compounds whose immense importance in agriculture and in industrial chemistry are well known.

III

ACTION OF PRESSURE ON SPEED OF REACTION

Researches in this domain, already very numerous, have been particularly fruitful. They have included a large number of systems, homogeneous as well as heterogeneous. Let us consider a few examples.

When submitted to pressures of several hundred atmospheres many compounds undergo transformations which, at ordinary atmospheric pressure and in the same conditions of temperature, would not manifest themselves except after periods of time undoubtedly very long. Thus, among the substances which we have studied by compression in glass tubes, the gas NO, repeatedly stable at the ordinary temperature, has been submitted to pressures running as high as approximately 700 atmospheres, after even a few seconds it presents indications of a curious decomposition which progresses rapidly and which we will refer to further on. At this point let us merely remark that it is characterized by the appearance of a liquid which is colored blue by the anhydride N^2O^3 formed. The oxide of carbon, at 320° C. and under 400 atmospheres, also undergoes a decomposition accompanied by a permanent contraction and the formation of carbon dioxide. Cyanogen can be heated at 220° C. for a very long time without being altered; at the same temperature, but under 300 atmospheres it is polymerized into paracyanogen, and also decomposes in part into its elements. In similar conditions acetylene also yields polymers of a brown color. The reactions between many gaseous substances are likewise favored by augmentation of pressure; we have proved this, for example, for the oxidation of sulphurous anhydride into sulphuric anhydride by compression of the mixture $SO_2—O_2$.

At this point it is advisable to make a remark concerning chemical reactions in general, and more especially those which affect gaseous substances. Aside from affinity, which is the origin of every chemical reaction, it is necessary to take account of the action of the substances called catalytic, which remain alien to the reaction itself which they nevertheless accelerate, but whose mode of action is not always very well defined. All solid bodies being, in particular, susceptible of acting as catalytic agents, it would be necessary, at least theoretically, to take into consideration the rôle of the receptacles containing the system under study. From this fact, it might become difficult to establish with precision, in the progress of a reaction, the part to be ascribed to compression.

Among the solids smooth glass is one of the least active bodies; hence the reactions studied in this material are for the most part very little influenced by the walls. But there are some, however, which are thus influenced to a degree so high that the action of the compression may be masked. Such a case is the formation of water from its elements. Thus, in operating at 400° C. upon a mixture $H_2—O_2$ we have found that the proportion entering into combination was, after an equal lapse of time, almost the same at 300 atmospheres and at ordinary atmospheric pressure. At first glance this result would seem to indicate that the elevation of the pressure has no influence. In reality, this influence is far from being null. In fact, when the mixture is compressed, it is, for an equal mass, in the presence of a surface of glass much less extensive than at low pressures, and since the glass in this case plays an important rôle as an accelerator, the compression has done nothing except to compensate for the diminution of extent of the walls.

To profit by all the favorable circumstances and obtain the maximum effect, the experimenter may therefore have recourse with advantage to the combined application of temperature, pressure, and suitable catalyzers. Many recent investigations have been executed in this way. Let us mention a few.

Ipatieff, Brochet, and others, in operating with compressed hydrogen, and in the presence of different catalyzers, have succeeded in hydrogenating a large number of organic substances, and obtaining very useful substances whose preparation by other methods would have presented great difficulties.

As an example of a gas reaction upon a solid favored by pressure, let us cite that which enabled the eminent chemist Mond to prepare the carbonyls of many metals: iron, cobalt, molybdenum, ruthenium; the carbonyl of the latter metal, in particular, requires temperatures of about 300° C. and pressures of many hundred atmospheres. These very volatile bodies, once formed, decompose very readily at ordinary pressure if the temperature be raised, yielding a metal of great purity. Mond has even founded upon this reaction a process utilized industrially for the manufacture of pure nickel.

Another problem which has strongly attracted the attention of investigators and of industrials of late years is the distillation of petroleums and mineral oils with a view to obtaining more valuable substances. American experimenters have proved that the effecting of this distillation under pressure favored the formation on the one hand, of essences, or bodies with a lower boiling point, and on the other hand of aromatic hydrocarbides, such as benzine, toluenes, xylene. The enormous importance of these substances at present is well known.

Applied to liquid bodies, simultaneously with elevation of temperature, strong pressures are also capable of accelerating certain reactions in large measure by permitting the maintenance of the liquid state far beyond the point of ebullition at ordinary pressure, and up to the critical point.

In causing water, liquid at 300° C. (which presupposes a pressure of about 100 atmospheres) to react upon iron, Bergius obtained a very rapid and very complete oxidation of the metal. This reaction, which is still more accelerated by the presence of certain catalyzers (metallic chlorides and metals), constitutes a very advantageous method of preparing hydrogen. By this process, already applied industrially, the price of this gas, of well-known utility for the manufacture of ammonia, for aerostation, etc., can be reduced to a few centimes (a centime = ⅕ of a cent) per cubic meter.

Systems entirely solid are no more refractory to the chemical action of compression. But in these systems the reactions are less accessible to systematic study; the extreme slowness of diffusion, the absence of renewal of surfaces of contact, are causes which prevent the phenomena from progressing regularly, and the employment of extremely intense compressions would appear necessary.

We shall close here this brief enumeration, which does not pretend to be complete. But before terminating this chapter, I wish to call attention to a general character which is peculiarly striking in the majority of these investigations; this is the somewhat rough approximation of relative results to the rôle played by pressure alone in the acceleration of the reactions. Save for researches in homogeneous liquid systems where the action of the compression is moreover very feeble, these results are, in fact, rather of a qualitative order.

A special study of the decomposition of nitric oxide has given us some more precise information upon this point, which is one of capital importance in our opinion.

This decomposition is particularly well-suited to the end to be attained, for its progression, strongly accelerated by the compression, possesses a rate of progress which is regular and is unaffected by the action of the container, at least in the conditions in which we have studied it. By the aid of experiments made in the interval between 100 and 700 atmospheres we have established the differential equation characterizing the speed of this transformation. This equation has enabled us to estimate the periods of time corresponding to the decomposition of NO, at the ordinary temperature, up to a given fraction, and for different initial pressures; the following list shows some of these values:

Initial pressure in atmospheres	Fractions decomposed	Times
400	1/50	8 hours
1	1/50	910 years
1	1/1,000	51 years
1	1/10,000	64 years
2	1/1,000	19 years
2	1/1,000	3 months
10	1/1,000	10 hours
1,000	1/1,000	1 minute and 40 seconds

By way of verification we have calculated that the time necessary for the appearance of the liquid phase in a tube filled at 50 atmospheres was nearly a year; but, after the eleventh month, we noted, in fact, the existence of a little droplet of the blue liquid. In

a tube filled at 720 atmospheres, the column of liquid had attained a third of the length in forty minutes.

IV

CONCLUSIONS

The facts which have been stated emphasize with sufficient eloquence, the importance of the chemical action of pressure in phenomena of equilibrium and in the evolution of systems towards an improved stability. This evolution appears to us to be general, and compression will assist in making it evident in the case of systems which in ordinary conditions undergo transformations too slow to be appreciable. We believe it is worth while, however, to add a few words in concluding to show that the study of this action is susceptible of leading to consequences of an extent not less general.

The pressure of the atmosphere in which we accomplish the acts of our life and the chief part of our researches, is merely a special value among all those in the universe, and one which characterizes only the surface of our earth. Besides, in the interior of this globe, in the other stars, and in the spaces which separate them, are found a series of pressures ranging from the feeblest approximating an absolute vacuum, up to enormous pressures, stated in terms of millions of atmospheres. If, by a simple supposition, the ordinary pressure in an atmosphere of the same composition as our own had a value several hundred times as great, how the aspect of things would be changed. Some of the results could be predicted. Doubtless a vast number of new combinations, (peroxide and others) would exist or would rapidly be formed; on the other hand, bodies considered to be stable (NO, CO, etc.), would have only an ephemeral duration. It is advisable therefore that in forming cosmogonic theories we should take account of the influence of the factor of pressure side by side with that of temperature.

In the stars the principal rôle of high pressure, is, as it appears to us, to counterbalance the action of high temperatures and to permit the existence of the molecules of simple bodies or of combinations, which at moderate pressures would be completely dissociated. Naturally we can not be too prudent in this domain in attempting to apply to extreme conditions of pressure and temperature theories which have been verified solely within the limits accessible to us.

We offer, however, by way of primary indication, a table which we have established for the dissociation into atoms of hydrogen, a gas which follows known laws particularly well:

Pressure 1 Atmosphere		Temperature 600°	
Temperature	Proportions dissociated in per cent	Pressures in atmospheres	Proportions dissociated in per cent
3,000	6	10	80
4,000	25	100	53
5,000	92	1,000	19
6,000	99	100,000	2

At 6,000° and at pressures of several atmospheres, conditions which are approximately realized at the surface of the sun, hydrogen, therefore, would be reduced almost completely to the atomic state; on the other hand, at the same temperature, but under 100,000 atmospheres of pressure, it would be for the most part in the molecular state. If it obeys this same law up to the pressures and temperatures attributed to the central regions of the sun, hydrogen would there be dissociated in the proportion of 10 per cent. It follows from these considerations that not only the polyatomic molecules of simple substances, but also those of more or less complex compound substances are entirely capable of existing at very great temperatures, provided the pressures are sufficiently great.

Starting from these same premises concerning the action of pressure, we have recently announced some ideas according to which the purely chemical phenomena of nature may participate in an important degree in the occurrence of solar radiation, whose origin is still so mysterious, yet which touches us so closely.

This exposition will have demonstrated, we hope, the great interest which exists in the domain of pressure researches for the scientific investigator. It is also one of those which most offers opportunities of success; for if, in the case of temperature, researches are forcibly limited, at the lower end of the scale, by the extreme slowness of reactions, and at the upper end by the absence of sufficiently refractory substances, in the case of pressure their field is susceptible of great further increase, thanks to the continual and almost astounding progress of experimental technique. Let us hope that in the future this progress will be more and more exercised in a direction useful to mankind.

An Air Meter for the Rand

An account of the air meters designed in connection with the Victoria Falls and Transvaal Power Scheme, and of some subsequent work carried out by himself and Messrs. George Kent in developing the commercial metering of air, gas, and steam, was given by Mr. J. L. Hodgson in a paper before the Institution of Civil Engineers.

The necessary experimental work having been carried out in 1909, the first meters were constructed in 1910 and erected on the Rand in 1911. Since that date a number of additional meters have been sent out to Johannesburg, and now the aggregate capacity installed is over 300 million horse-power hours per annum.

In the agreement between the Power Company and the consumers it was stipulated that the meters should be accurate to within 3 per cent either way. The air-unit, in terms of which the meters were to register, was to be the quantity of air which would be compressed from mean atmospheric pressure and temperature on the Rand to the pressure of delivery by the expenditure of one kw.-hour of energy in an isothermal compression process of the same over-all efficiency as obtained between the indicated horse-power in the steam cylinders and the air delivered in the case of certain specified compressors then in use on the Rand.

VENTURI AND GATE AIR METERS

It was provided that the Power Company and the consumers should each install their own meters, which should preferably operate on different principles, and that the charges should be based upon the means of the readings of the two meters thus installed at that point of supply. The author accordingly designed two forms of meter; in one, for the Power Company, the flow of air is measured in terms of the differential pressure obtained from a Venturi tube of known up-stream area and throat-ratio; and in the other, for the consumer, in terms of the angular displacement of a weighted gate hung in the airway.

The size of the throat of the Venturi tube installed at each point of supply is so chosen that in every case the same differential pressure is obtained at the maximum flow called for by the consumer. Thus, all the recorders, the action of which depends on the differential pressure, are identical and interchangeable. When it is desired to increase the capacity of any meter, all that has to be done is to replace the existing throat-section of the Venturi tube by one of larger diameter and to alter the gear-wheels in the counter-train of the recorder. In the case of the gate-meters the capacity is increased even more easily, by increasing the loading of the gate in such a way that the ratio of the initial and final moments tending to close it remains unchanged. Thus, if the change of loading is always so made that the center of gravity of the moving parts remains on the line passing through the original center of gravity and the axis of the bearings, then the original calibration still holds good, and the quantity passed by the meter is increased in the ratio of the square root of the new loading to that of the old.

As neither form of meter is arranged to register at a load higher than the maximum for which it happens to be adjusted, a simple cut-out valve comes into operation when the maximum capacity is reached, and another type of valve, also designed by the author, is so arranged that only a fixed maximum quantity of air can be taken. It does not cut off the consumer when the flow for which he has contracted has been reached, but simply limits the air he can take to that maximum. A number of these limit valves are in use in various parts of the world as filter-beds modules controlling the rate of filtration of potable water.

ECONOMY IN AIR

The importance of securing the highest possible economy in the use of compressed air in mining is shown by the fact that in the case of those mines on the Rand which use machine stopping approximately three tons' weight of air has to be delivered underground for each ton of ore milled, and that the power used in compressing the air for the rock-drills is at least equal to the mill-engine power. This economy can be obtained by maintaining a uniform pressure of supply, by employing only the most efficient tools and maintaining them in a high state of efficiency, by laying the underground mains of sufficient capacity, and by preventing leakage. Those in charge of the compressed air distribution on the Rand consider that by careful attention to detail at least 20 per cent of the air now required could be saved. Considerable economies can be obtained by periodically determining the consumption of each type of machine, both on the test bench and under working conditions, but to secure the most efficient check on the air-consumption permanent counter-meters must be installed on the main distribution lines and on the principal branches.

In the fan proportional meter, which fulfils the requirements, an obstruction is placed in the airway to divert a portion of the flow through a shunt circuit, where it drives a small impulse-wheel connected by gearing to the counter of the meter. The motion of this wheel is retarded by a fan attached to it, and its speed of revolution is made to vary with the pressure by deflecting, in such a way as not to alter the resistance of the shunt circuit, a portion of the air which drives it. Since the motion of the impulse wheel is retarded by a fan, the resistance of which to rotation is proportional to the density of the air in the main and to the square of the speed of revolution, the area of the undeflected portions of the jets must vary approximately as the cube of the pressure, if the speed of rotation is to be proportional to the energy passing. This is effected by making the nozzles of the necessary cross-section, and deflecting a portion of the air issuing from them by plates whose motion is determined by the pressure in the main. These plates are moved by sealed Bourdon tubes which are subjected externally to the pressure of the air in the main.

Finally the author described steam-metering instruments of his design in which a flexible diaphragm controlled by springs is used to measure the differential pressure, and also the application of the Venturi to be used in metering large gas mains.—*London Times Engineering Supplement.*

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Table of Contents